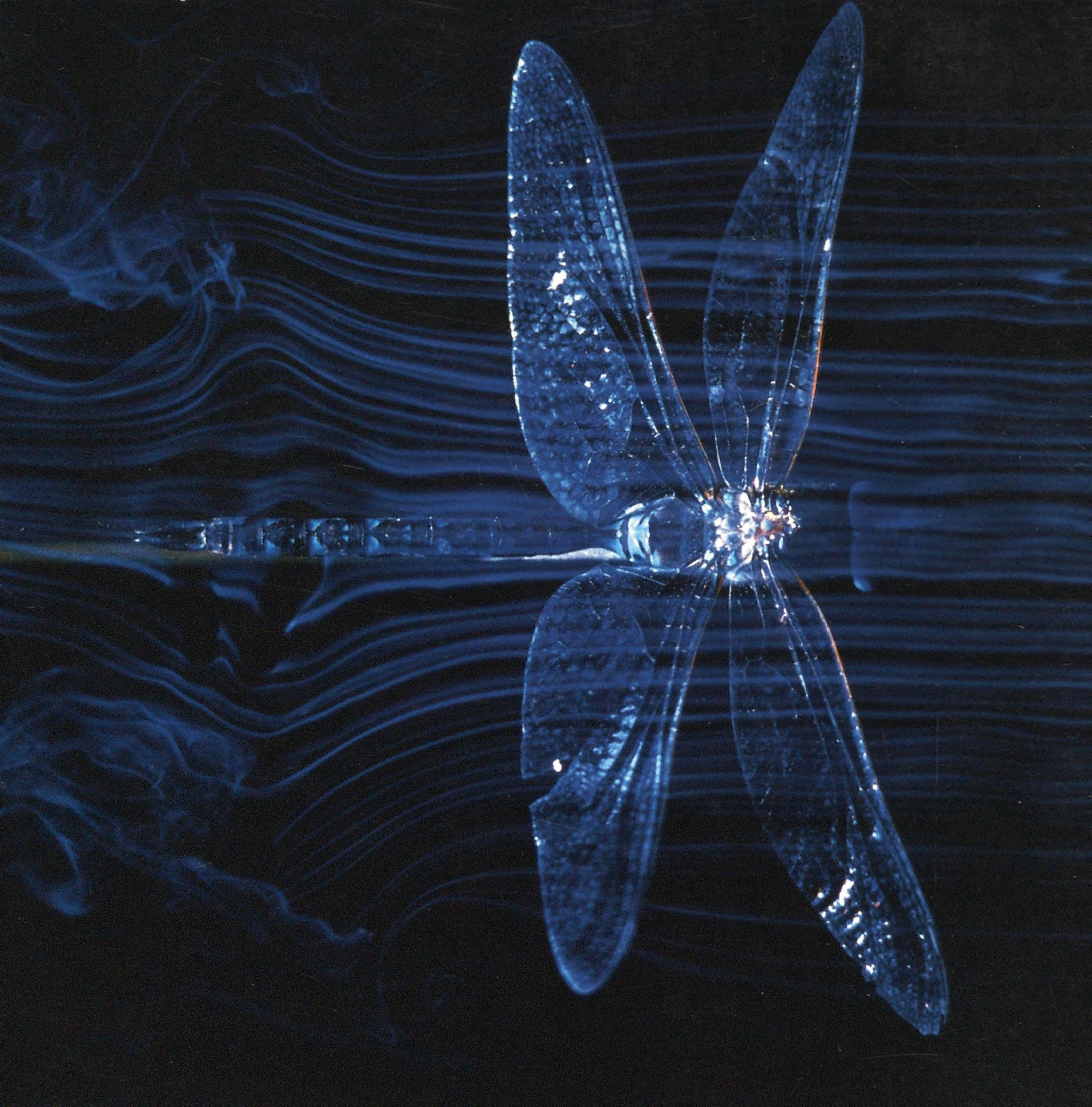
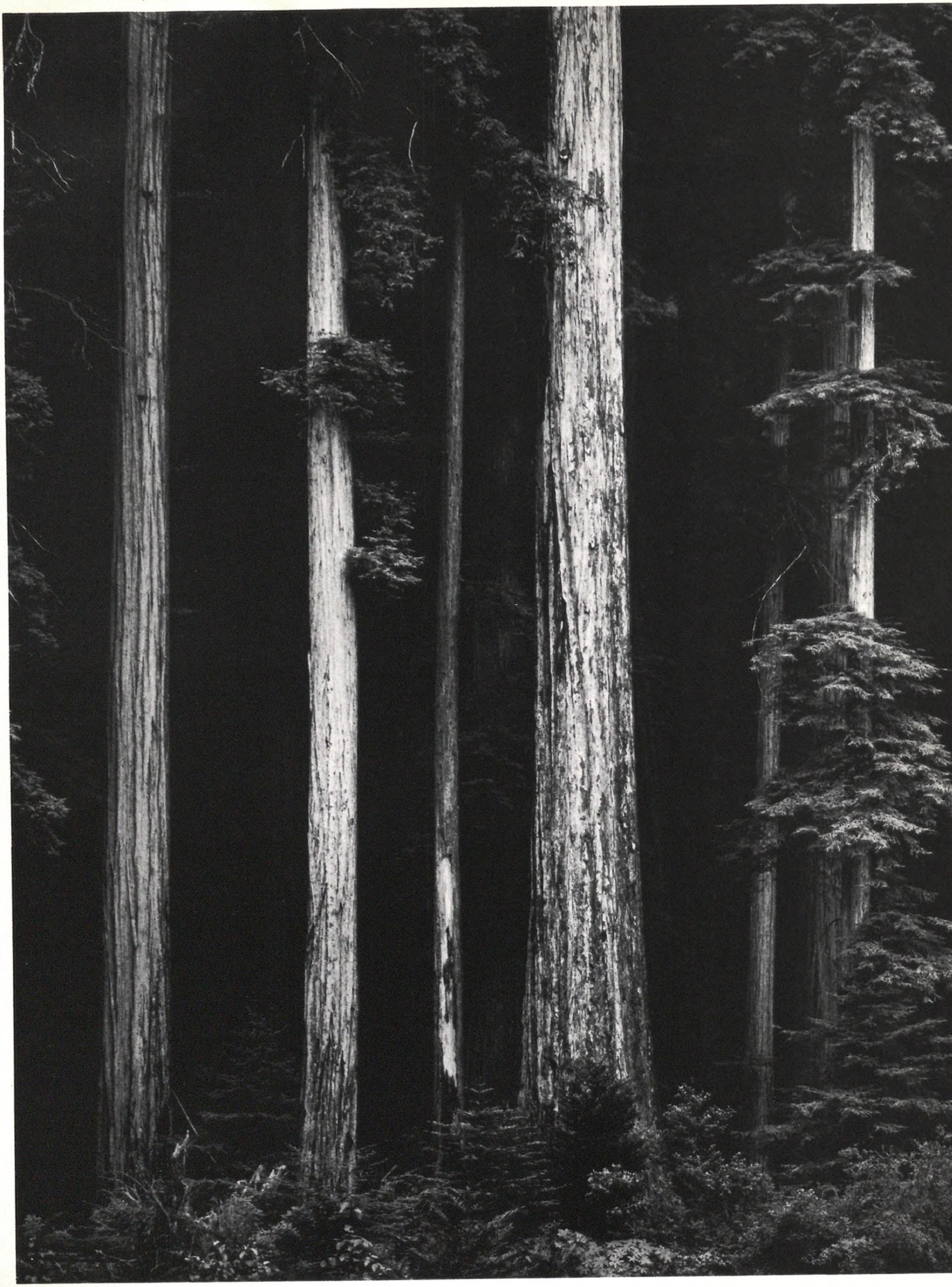
October/November 1986

AIR&SPACE

Smithsonian

The dragonfly's ancient design has modern aerodynamics aflutter





Redwoods, Bull Creek Flat, Northern California. Photograph by Ansel Adams. Courtesy of The Trustees of The Ansel Adams Publishing Rights Trust.

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October/November 1986 Volume 1, Number 4

AIR & SPACE
Smithsonian

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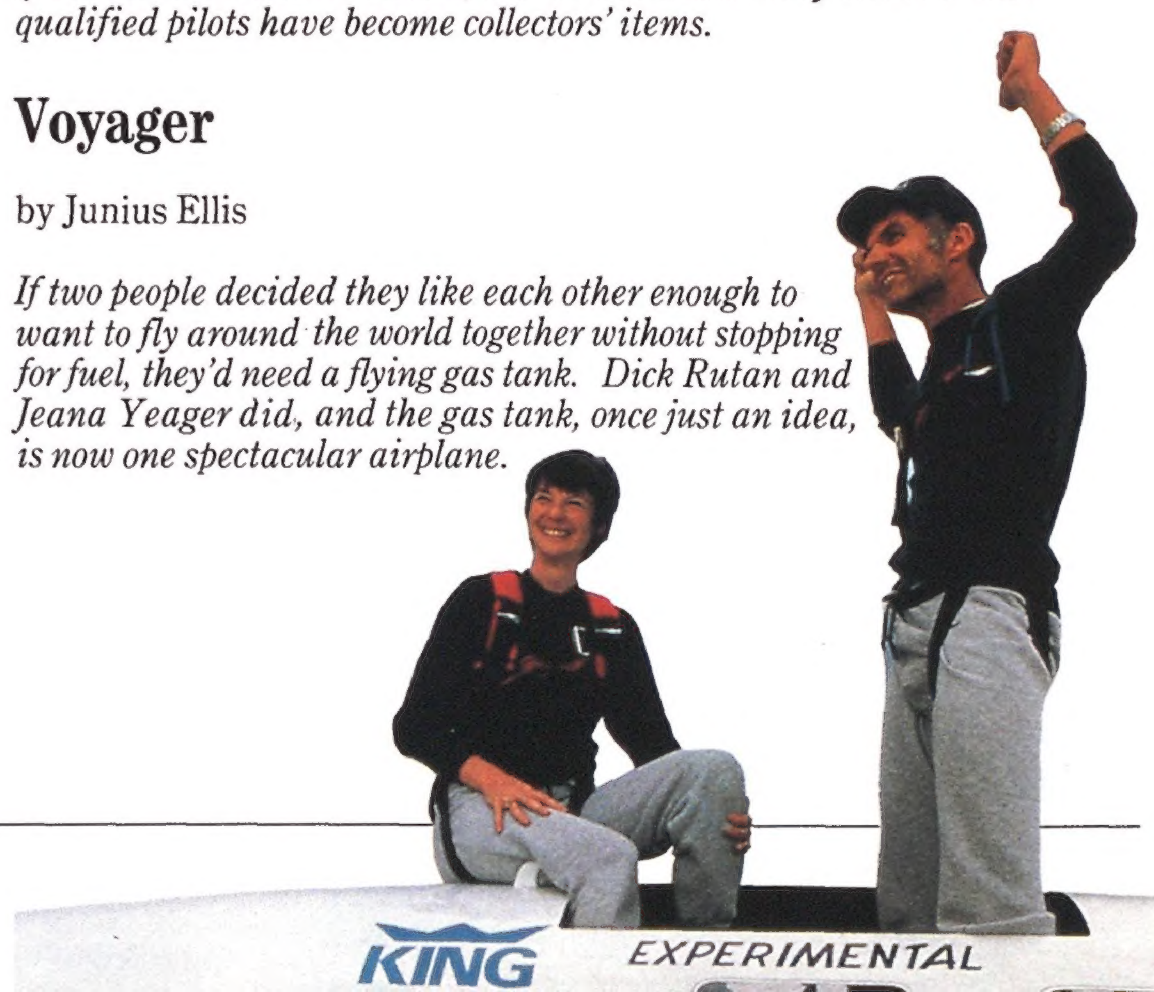

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cover: *Paul Chesley's camera froze the flow in a wind tunnel as the wings of a dragonfly created eddies in smoke streams.*

The Charter

We're often asked, "When is a large artifact considered too big for the National Air and Space Museum?" It's a good question, one that addresses the considerations we confront when we want to exhibit or preserve such craft as airliners and space shuttles. Donors offer artifacts that could interest researchers and visitors, but storage space and cost must always be considered.

The Museum's charter directs us to collect objects that tell the story of air and space history, but we are guided by an acquisition policy that imposes more rigorous criteria. We accept articles of national importance that played a significant role in history or were pivotal in the development of a key technology. Artifacts are also accepted if they are associated with famous people or are particularly representative of a specific category of aircraft. We turn down far more artifacts than we accept, and we consider storage costs in every case.

Occasionally, someone will suggest that photographs, drawings, or sections of larger vehicles would fill our needs without consuming so much storage space. But if one thing is apparent from our ten years of experience, it is that our visitors feel a direct connection with the genuine article that simply cannot be matched by photographs or replicas.

The Museum divides its artifacts into two classes. One category is made up of the objects that actually achieved an important feat—the Wright *Flyer*, the *Spirit of St. Louis*, the Apollo 11 command module. But circumstances occasionally force us to settle for less than the real thing; thus, the other category includes artifacts that have departed Earth forever or have been destroyed—Vanguard, *Mariner 2*, and *Skylab*, for example. In those instances, we acquire a back-up craft or build a replica that's as accurate as we can make it. But the public's preference for the real versus the replica is noticeable. What may be less apparent is the importance of having the genuine article for research purposes.

We are more careful when we evaluate large objects than we are with smaller ones to weigh the artifact's significance against its storage requirements. It is conceivable, for instance, that the Museum might collect examples of both the Piper Cub and the Taylorcraft. Both are light airplanes, similar in design, technology, and performance, yet both are of interest because of their long-standing popularity. It would be inconceivable to take on both a McDonnell Douglas DC-10 and a Lockheed L-1011; wide-body airliners represent an important era in air transportation, but there's room for only one in the Museum.

The availability of a large aircraft in other museums also influences our decision to acquire one like it. The Air Force Museum at Dayton, Ohio, has a huge Convair B-36, so we do not plan to seek one. On the other hand, both museums exhibit similar models of smaller aircraft with more universal appeal.

We believe that Museum visitors 100 years from now will be as insistent on seeing real examples of a shuttle orbiter, a Concorde supersonic transport, and a Boeing 747 jetliner as today's visitor is on seeing the original Wright *Flyer* and our moon rock. We can't begin to imagine the effect these marvelous aircraft will have upon the future visitors who view them in the Museum. The National Aerospace Plane will help usher in the twenty-first century and the beginning of our second hundred years in air and space. By the time the first Space Plane is on display at the future Dulles Wing of the Museum at Washington-Dulles International Airport, what other air and space craft, what space stations, what breakthroughs in culture, politics, and law will the world have seen?

—*Walter J. Boyne*

Walter J. Boyne resigned from the National Air and Space Museum in August.

NASM

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Letters

Peace Talks

I would like to settle the argument between those letter writers who want more "air" and those who want more "space." Although I'm not an airplane fan, I believe air and space belong together: each should receive equal room. There may not be too many current space stories at the moment because of the *Challenger* accident, but there is a lot of history to report, and there aren't many magazines for us space fans.

So both sides, drop your swords and shake hands.
Rhonda Carlberg
Barre, Massachusetts

Balancing Act

After reading the "Bioflight" article (June/July), Ray Bright's "three-color-axis" system made excellent sense to me and even explained something I had been doing myself for some time.

As a small child I had a very bad ear infection—in the days before antibiotics—which damaged the balance canal in one ear. I had "learned" balance first by relating to what I saw and what part of my body was in contact with the ground. Without realizing it, I started relating spatially within myself and my immediate environment. Thus his system helped explain to me what I was doing.

I have a strong hunch that Mr. Bright's training system would be a big help to people who suffer from any physiological problem affecting their balance.
Patricia S. Miller
Garberville, California

Flight Plan

I was quite impressed with "The Might of the Microburst," finding it very informative and entertaining. I agree that the best way to survive a microburst is not to fly through it. However, with the exception of the plan offered by Angelo Miele of Rice University ("Wind Shear: A Pilot's View"), I noticed that the recovery technique seemed to be a maximum performance climb (on the edge of a stall). I would like to propose a scenario for Miele to test.

Let's accept at best a slight attempt at a climb, or more preferably, a slight pilot-induced rate of descent, allowing the aircraft to descend into ground effect or as low as possible before leveling off to avoid obstacles. By descending, the pilot allows his aircraft to accelerate at a much faster rate. As airspeed increases, less thrust is required to maintain airspeed and thrust may now be used for a climb. If the pilot had moved the throttle forward at the descent, there would be time for the engines to spool up to a point where a climb with the tailwind is possible. The pilot should not attempt to land once he makes the decision to use ground effect.

This scenario may not work, but it is a different way to attack the problem caused by the low thrust/low airspeed environment of the microburst.
James P. Crail
Castle AFB, California

What a Drag

The article on drag racing ("The Cars Won't Fly," August/September) has nothing to do with air or space. If I wanted to read about drag racing I would have subscribed to *Hot Rod Magazine.*

I see that a future issue will have an article on windmills. This has as much to do with air and space as hot rodding does.
Kevin O. Brennan
Long Beach, New York

Army vs. Navy

Reading Otha C. Spencer's account of U.S. Army Air Force "Hurricane Busters," ("Above & Beyond," August/September) brought back memories. I have recorded over 1,000 hours flight time as a crew member "meteorologist" with the U.S. Navy assigned to the "Hurricane Hunters" Early Warning Squadron VW-4. The squad-

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ron consisted of eight Super Constellations based between Jacksonville, Florida, and Roosevelt Roads, Puerto Rico.

Going into the eye of a hurricane, we'd fly at low altitude (300 to 800 feet) just below the base of the clouds. This was required to estimate the wind speed from the waves and spray. Believe me, at 130 to 140 knots [150 to 161 mph], it was one white streak before we entered the eye.

Let's give credit where credit belongs: we in the U.S. Navy were also "Hurricane Busters."

Anthony Kamanes
New Hyde Park, New York

Otha Spencer replies: I certainly did not intend to neglect the Navy in my story, and the Navy was given credit for flights. My purpose was to outline the beginnings of hurricane reconnaissance. In 1944, we were pioneers, and our squadron was the first whose specific mission was to scout the storms. You and others have carried on that mission.

If I get enough response from other hurricane busters, maybe we can get together sometime as a group.

No Defense

George Larson's "Dinner with Ken" ("Soundings," August/September) mentions a March 1970 order by Defense Secretary Robert McNamara to scrap the tooling for YF-12A production. McNamara's resignation in 1968 would indicate that the unexplained destruction orders probably occurred several years earlier than 1970. An explanation of this and many other decisions that emerged from the Department of Defense during the McNamara years will probably be left to conjecture by historians—historians who are only now detailing those final decisions made by General George A. Custer in 1876.

Wayne Thurn
Grants Pass, Oregon

George Larson replies: Thurn is correct. McNamara was no longer Secretary of Defense when the tooling was destroyed in 1970 and therefore could not have "personally supervised" their destruction. The original order was issued in 1967, but not carried out until 1970. We regret the error.

Satisfied Customers

I have been enjoying my subscription to *Air & Space/Smithsonian.* The article on flying boats ("When Boats Flew," June/July) was the best lay magazine summary I have read on the subject. The August/September issue points out the reality of the "Space Plane" and gives a good look into the past in "New Guinea's Great Aerial Gold Rush."

The June/July issue impelled me to drive to Washington to visit the National Air and Space Museum from my new home in North Carolina.

Paul Dezendorf
Asheville, North Carolina

Being a meteorology student at the University of Michigan, I especially enjoyed the article on hail-cloud seeding in North Dakota ("The Battle of Bowman," June/July). In fact, I have written to them for information on the program—I'm definitely a potential pilot. The article on microbursts and wind shear was also exciting.

Air & Space/Smithsonian has airplanes, spacecraft, people, storms, and stars, as you have pointed out so well. Please keep up the wonderful diversity. I wish only that your magazine were published more often.

Cassi Paslick
Ann Arbor, Michigan

I appreciate the variety found in each issue of *Air & Space/Smithsonian.* While on vacation—camping in a remote area of Michigan—I can enjoy reading about an airport constructed in an equally remote area of Ireland ("Wings and a Prayer," August/September). I can learn more about wind shear ("Might of the Microburst"). I can even find reference to my favorite hobby, railroading, in the article about the "Orient Express" ("Space Plane").

Best of all, I can do all of this while observing flight in its purest form—the circling hawk high overhead and the aerobatics of the voracious dragonflies as they rid the skies of at least a few mosquitoes.

William J. Boyd
Winnetka, Illinois

Air & Space/Smithsonian *welcomes comments from its readers. Letters must be signed and they may be edited for publication. Address letters to* Air & Space/Smithsonian, *National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560.*

"Whoever you are, you're hired."

Breathing Lessons

Barry Fitzgerald

Pilots learn to spot the sinister onset of oxygen deficiency in a test chamber where high altitudes can be simulated by pumping out the air.

Altitude: 25,000 feet and holding. The eyes of the veteran pilot across from me look calm, but those of the officer trainee are darting nervously. Something is wrong. His face is pale and getting paler, its expression disoriented, not alert. And although his lungs are taking in a few billion trillion molecules of air with every breath, in fact he is starving for oxygen—suffering from what physiologists call hypoxia. At this altitude, he'll be unconscious in another minute or so; death will eventually follow.

An Air Force observer has been watching this student intently and, moving in, shoves an oxygen mask into place over his blue-tinged lips. I'm doing fine; I've had my mask on all along. Through our helmet intercoms, the instructor calls attention to the student's momentary stupor and reminds us how dangerously insidious hypoxia can be. Our demonstration over, the cabin pressure returns to normal as we return to ground level.

Actually, we never left the ground. The aircraft "cabin" is really the high-altitude test chamber at Pease Air Force Base in New Hampshire, one of some two dozen such units maintained by the Air Force to train flight personnel on the hows and whys of breathing properly up high where the air gets thin. Only a few dozen pilots took the first classes in 1942. Now about 45,000 people take the course annually, not counting those handled by the Navy and Army in separate facilities. The military services require all civilian passengers aboard high-altitude airplanes to have chamber training. That's why I'm here, renewing my "license" to travel aboard research aircraft. Most of the others are active pilots who, I suspect, would rather be elsewhere, flying something real.

But the Air Force knows that many of its fighter jocks get a little cavalier about using their oxygen equipment. When that happens, disaster can result. Hundreds of serious military mishaps occur each year, many preceded by pilot blackouts. Given the cost of today's high-performance jets, not to mention the value of those aboard them, these refresher courses take on more than passing importance.

Our ride in the "tank" is preceded by more than five hours of classroom instruction on how to recognize hypoxia's symptoms, use oxygen equipment, and react during a sudden decompression. Throughout the session, I couldn't stop thinking about the big scene in the movie *Airport*, when a bomb rips a huge hole in the side of an airborne Boeing 707, and the escaping air sucks out everything that's not tied down. In the movie, decompression is strong enough to drag passengers down the aisle despite their futile attempts to hang on. Actually, the escape of air wouldn't be nearly that violent. But a real decompression occurred last April when a bomb exploded in the cabin of a TWA airliner over the Mediterranean. Four victims sitting nearby vanished through the hole.

After the sobering lectures, we are issued the helmets and masks that will sustain us once in the chamber. The mask's fit has to be airtight, and that means muzzling the face so snugly that my eyes surely must bulge out. In a previous class, I saw a man forced to shave part of his beard to get the mask to seal.

Once inside the tank, we sit down and hook up our masks. A hose leads from each mask to an individual pressure regulator (a kind of self-adjusting valve), which controls the flow from a high-pressure oxygen supply. A set of switches operates the regulator. It looks complicated, but the regulator panel has one simple virtue: in emergencies, the switches are merely flipped up. This causes 100 percent oxygen to surge into the mask with such pressure that exhaling—and speech—becomes difficult.

The chamber itself is only about 12 feet long and half that in height and width, but the monstrous plumbing that attends it could fill a small hangar. Small observation ports of inch-and-a-half-thick glass punctuate its battleship-gray steel walls, and the instructor sits behind a larger window at one end. Mounted on the bulkhead opposite him is the tank's door, a massive gasketed plate that lacks any kind of real closure mechanism—the reduced pressure inside is more than enough to keep it sucked shut. Two observers join our class of 13, with several others stationed outside to keep an

eye on us. The door swings into place, and I hear the giant pumps begin to whine.

We first take a short hop to a simulated altitude of 5,000 feet, just enough to test our ears and sinuses. As air pressure falls, gas trapped within the inner ear has little or no trouble exiting through the small passageway, called the eustachian tube, to the throat. But getting air back in can be a problem once pressure rises again, especially if you have a head cold. The frequent result, as most airline passengers know, is a painful distortion of the eardrum. The standard countermeasure is to "Valsalva"—to pinch the nostrils shut and try to blow air from the lungs through the throat and up into the ears. It's not spelled out explicitly, but anyone who can't successfully accomplish this flunks the decompression course.

Half an hour passes as we sit quietly, inhaling pure oxygen and listening to our own rhythmic breathing. This purges our blood of nitrogen that might otherwise form dangerous bubbles at the low pressures we'll soon experience. A final thumbs up signals my readiness, and with the whoosh of a valve we head "up." It takes seven minutes to reach 35,000 feet, but I start to feel the effects long before we get there. Passing through 18,000 feet, we reach a pressure half that at sea level. I sense a slight fullness down in my gut, and a tied-off rubber glove hanging in the corner reminds me why. It was hanging limp but has now swelled into a recognizable hand as the air trapped inside it expands. Bubbles from my partially digested hamburger are doing the same thing inside me.

At 35,000 feet, the glove resembles a bloated udder, and that's just how we feel. The pressure has dropped to 2.9 pounds per square inch. A bubble of gas now occupies several times its volume at sea level. I'm decidedly uncomfortable. "Don't try holding it in," the instructor at the window admonishes with a grin. I wince when I think that this training used to go 8,000 feet higher. Our time at peak altitude is mercifully brief, and the pressure soon begins to rise steadily in a "free fall" drop lasting just under a minute. The discomfort eases in my gut but builds in my head. A Valsalva now and then keeps the inner-ear pressure in balance.

We level out at 25,000 feet, and on cue half the class members remove their masks. They are about to experience hypoxia first-hand. At this altitude the time of "useful" consciousness (enough awareness of what's going on to take corrective action) is only three to five minutes. Some people take longer to succumb, though succumb they surely will.

Now the rest of the class goes off oxygen. For me, the first symptoms are a tingling in my fingers and feet, followed by a light head. Others get blue around the fingernails and lips, shaky hands, a mild headache, or loss of peripheral vision. Once, during a previous session in the tank, I let things progress a little too far, and consciousness literally ebbed away despite commands barked by an observer crouching right in front of me. And that's just what is happening to the student officer today. This time, no one has to remind me to slap the mask back on. Our descent back to ground level is uneventful, save for the comical combinations of contorted jaws, pinched nostrils, and puffed cheeks as we clear our inner ears.

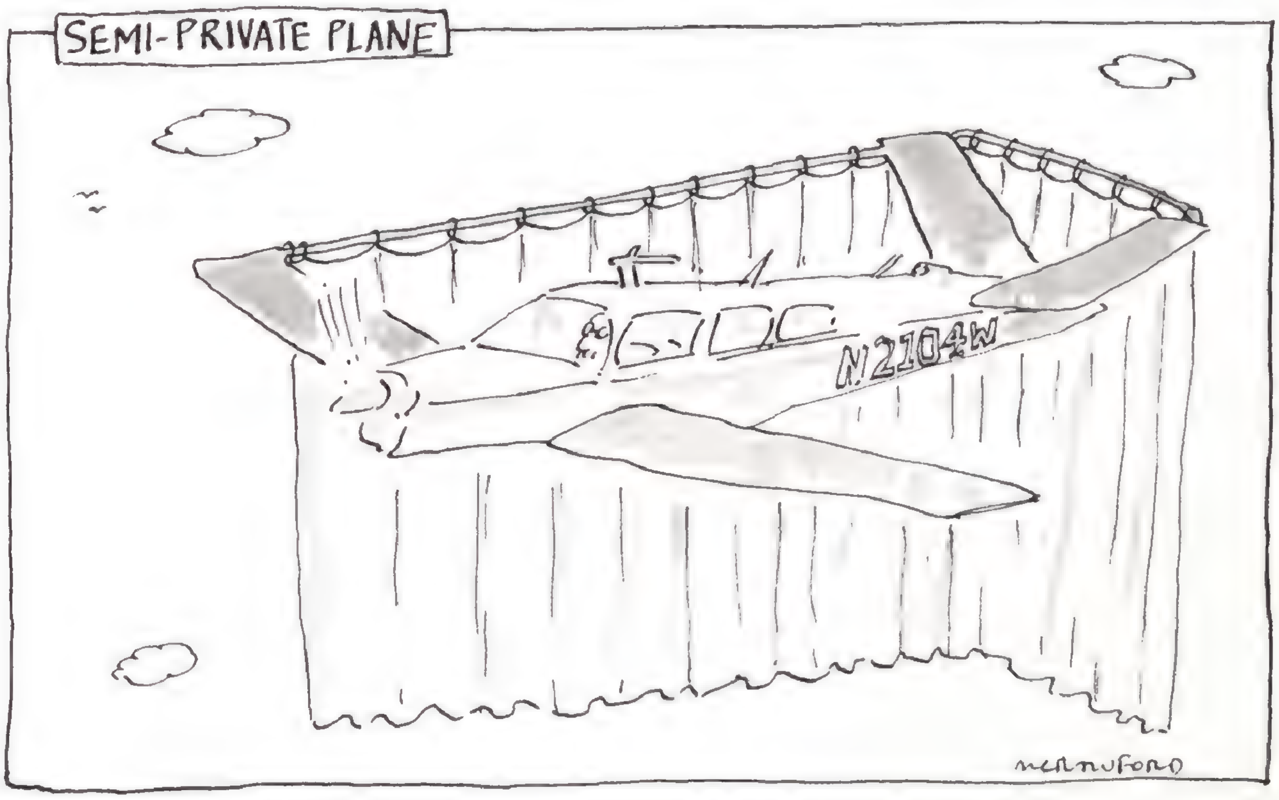
While it isn't always easy to pick up hypoxia's subtler effects, there's no mistaking the immediate danger presented by rapid decompression. Depending on its size, a commercial airliner can take up to a full minute to lose pressure through a large hole. But in the much smaller confines of a fighter cockpit, the time to total air loss collapses to only a second or two—not much time to react, considering that rapid decompression also reduces the time of useful consciousness by half.

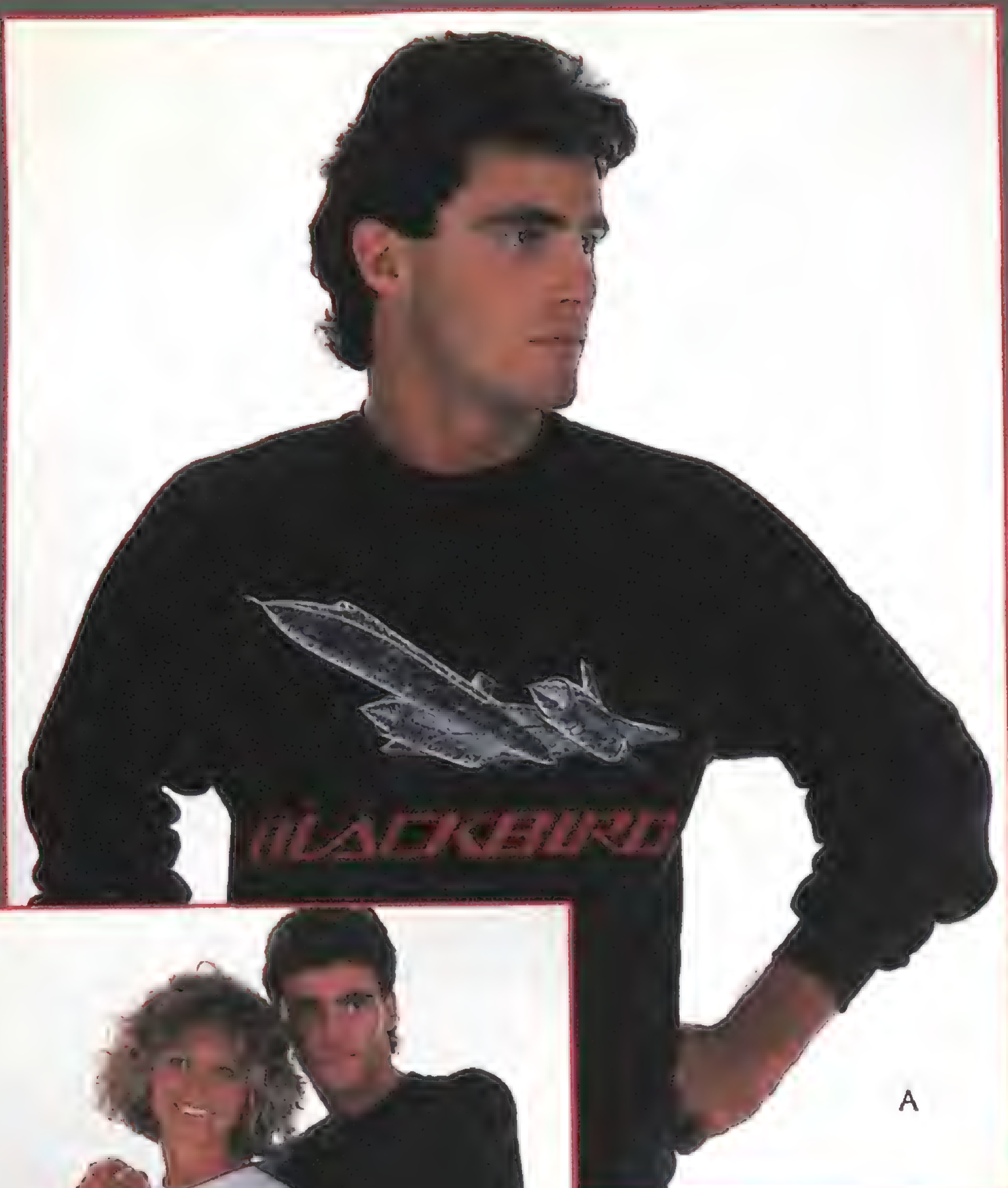
The Air Force maintains its pressurized cabins at a pressure equal to that normally found in the atmosphere at 8,000 to 10,000 feet, and oxygen masks are required when flying any higher. By contrast, most commercial flights maintain a cabin air pressure equal to about 5,000 feet. And those little yellow oxygen masks that drop from the ceiling of the airliner's cabin? "They're good to maybe 25,000 feet," says Major Robert Zellers, who heads the flight physiology group at Pease. "But that assumes no one panics or hyperventilates." Zellers points out that hyperventilation (breathing too rapidly) brings on many of the same symptoms as hypoxia, including blackouts.

For the final act at Pease, our class clambers by foursomes into a smaller chamber that packs a good decompression wallop: from 8,000 feet to 22,000 in one and a half seconds. The idea is to catch us unprepared, and the instructors usually resort to some distracting ruse—which usually works. Our casual conversation ends when the main valve opens suddenly with a cannon-like bang, followed immediately by three events: first, the air from my lungs is sucked out—literally—as the pressure falls; second, my ears pop once or twice as their passageways vacate; third, and perhaps most surprising, is that a dense fog forms instantaneously and clouds the chamber. I grope for my oxygen mask and throw all the regulator switches to their emergency settings. "No problems here," I signal by thumb. The fog clears as we descend back to the safety of sea-level pressure.

All this training, of course, offers no more than a simulated glimpse of real situations. Yet the chamber rides are not without stress and some legitimate danger (at least one fatal heart attack has occurred). I learn to trust the oxygen mask and its ability to sustain life. I gain a much better appreciation for the inherent rigors of even routine military flight, not to mention combat missions. And I get a small orange card, a badge of sorts, that for three years will let me fly up to nine miles high. It's not exactly a ride on the space shuttle, but it's a first step.

—J. Kelly Beatty





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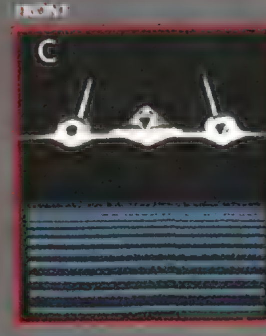

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A Family Reunion

Dorothy Michele Novick

Yellow wings straining against the headwind, the Piper J-3 Cub drifts down from the gray skies over Pennsylvania's Bald Eagle Mountains and seems to hover over the narrow concrete runway.

Standing alongside the strip, John Gelasi gives a running commentary on the pilot's technique. "He's looking a little burbly out there now," Gelasi says, as the airplane's wings seesaw a few feet above the ground. Abruptly, the Cub's fat main tires hit the runway and bounce, the tailwheel dropping a second later. "Shoulda had all three wheels down at once," Gelasi grumbles.

It was the kind of good-natured derision heard at William T. Piper Memorial Field for an entire week in July, as pilots from all over the country swooped into Lock Haven for the first Piper Cub fly-in. Dubbed by promoters "A Sentimental Journey to Cub Haven," the event kicked off a campaign to create a museum honoring Piper's line of light aircraft. By week's end, nearly 100 Cubs, and more than 500 other Piper airplanes, had journeyed to their birthplace.

William T. Piper's ubiquitous Cubs—some 14,000 of them—introduced recreational flying in the mid-1930s, to the extent that "Piper Cub" became a generic term for light airplanes. The last Cub was built in 1947, but you can still buy a used one today for about $12,000—if you can wrest it from its owner.

On the field, buttercup-yellow airplanes, with the characteristic black lightning bolts streaking along the fuselage, were lined up in orderly rows, along with revved-up Super Cubs and an occasional olive-drab World War II version of the Cub called the L-4 Grasshopper.

Nearby, in a muddy meadow, the reunion took on the air of a country carnival. Seated at picnic tables in a banner-bedecked pavilion, the Cub pilots, their families, and aircraft aficionados nibbled on deep-fried chicken, buttered sweet corn, barbecued pork sandwiches, and finally, chocolate-peanut butter ice cream for anyone who could find room for it.

In an ancient hangar just off the field, merchants sold spare Cub parts, commemorative pins, and sunny yellow T-shirts emblazoned with the Cub logo: a smiling bear face. Solemn emissaries of Pilots for Christ International issued pamphlets from a tent opposite the hangar.

Occasionally, the skies vibrated with the nasal drone of low-flying Cubs, causing visitors to set aside sandwiches and wander from the flea market to admire the fly-by.

The no-frills Cub is little more than synthetic fabric skin stretched over a metal and wood skeleton, powered by a 65-horsepower engine with its four cylinders protruding from behind the propeller like a pipe organ. You can't see over the Cub's instrument panel, what there is of it, and you must pay heed climbing into the cockpit for fear of breaking something vital, like the

wing struts or your lumbar vertebrae. It's a bare-bones design, and Cub pilots wouldn't have it any other way.

"Flying the Cub is like the difference between taking a ride in a nice, comfortable car and going for a joy ride in a Model T," says Gelasi, a chiropractor who first soloed in a Cub in 1947. "That's the charm of the J-3. It looks ugly, but we love it."

Some Cub owners flew to the rural airport, nestled between the Susquehanna River and the gently undulating mountains, from as far away as San Diego and Seattle. Flying cross-country in the snug two-seater is something like doing the bunny hop in a horizontal phone booth for what seems like an eternity. Because the Cub has only a two-hour fuel supply, most pilots made the trek in a series of slow, short flights spanning several days.

Ed Hoit, an instructor pilot for Boeing, and his co-pilot Marty Strong, a flight attendant for Western Airlines, gladly endured the tedious voyage. They flew more than 2,000 miles from Auburn, Washington, in just under 34 hours—not counting 19 fuel stops. Hoit, who has logged more than 10,000 hours in Boeing's 737, 747, and 757 airliners, seems an unlikely fan of light aircraft—particularly the no-radio, no-radar Cub. But after flying for Boeing all day, Hoit likes nothing better than to wedge his slender frame into his 1946 J-3.

"I have aviation in my blood, and to me, that means the Cub," Hoit says. "It's not like flying an airliner—the Cub can't be any simpler. It's flying for the sheer joy of it."

"Sentimental Journey" promoters are already planning next year's reunion, the 50th anniversary of the establishment of the Piper plant at Lock Haven. "With more advertising, we hope to see many more Cubs in 1987," says Ray Schaeffer, publicity chairman for this year's event, where 100 Cubs proved that "age before beauty" is more than just a courtesy.

—Jeff Meade

Music of the Sphere

Researchers can now pluck Earth's magnetic field lines like the strings of a giant harp. And the whistling, hissing, chirping sounds they elicit are serving as accompaniment to an exploration beyond the conventional boundaries of physical science.

The chief players in this planetary concerto are Robert A. Helliwell and his colleagues at STARLAB, Stanford University's laboratory for space, telecommunications, and radio science research. In 1950, Helliwell, an electrical engineer, encountered a little-known phenomenon called "whistlers." These are essentially the electromagnetic echoes of lightning and other atmospheric disturbances, and are audible in the two to five kilohertz range—well below the lowest AM radio frequency. Helliwell's scientific virtuosity was learning to generate whistlers at will by twanging the Earth's magnetosphere, then studying the results.

The magnetosphere—the medium for this message—is the zone of "magnetized plasma" 500 to 40,000 miles above the Earth. The magnetic field is created by the swirling of molten rock and metal in the planet's interior, and the lines of force loop from north to south like the pattern of iron filings connecting the poles of a bar magnet. The plasma is a mixture of subatomic particles—ions and electrons—that tend to arrange themselves along the field lines.

The plasma, Helliwell explains, is often "on the threshold of instability," like water ready to boil. Lightning at the Earth's surface is often enough to start things rolling. Electromagnetic energy from the crackling bolt explodes upward into the magnetosphere, excites the plasma particles, and can be propagated around the world or bounced from pole to pole in a matter of seconds. The energy travels as very low frequency radio waves, and by hooking an amplifier to a large antenna—even, Helliwell says, a long wire fence—listeners might catch the echoes of, say, a storm in another hemisphere in the form of a melodious whistle that drops in pitch.

Whistlers aren't the only magnetospheric strains, and the source is not limited to Earth. Instabilities can boil up into bursts of white noise called "hiss," or even into riffs of musical tones called "dawn chorus," so named because they sounded to British researchers like bird song at sunrise. Satellites flying by Jupiter, Saturn, and Uranus have picked up similar sounds—"and so," Helliwell notes, "it's almost guaranteed that wherever we go in the universe, we'll hear the same thing."

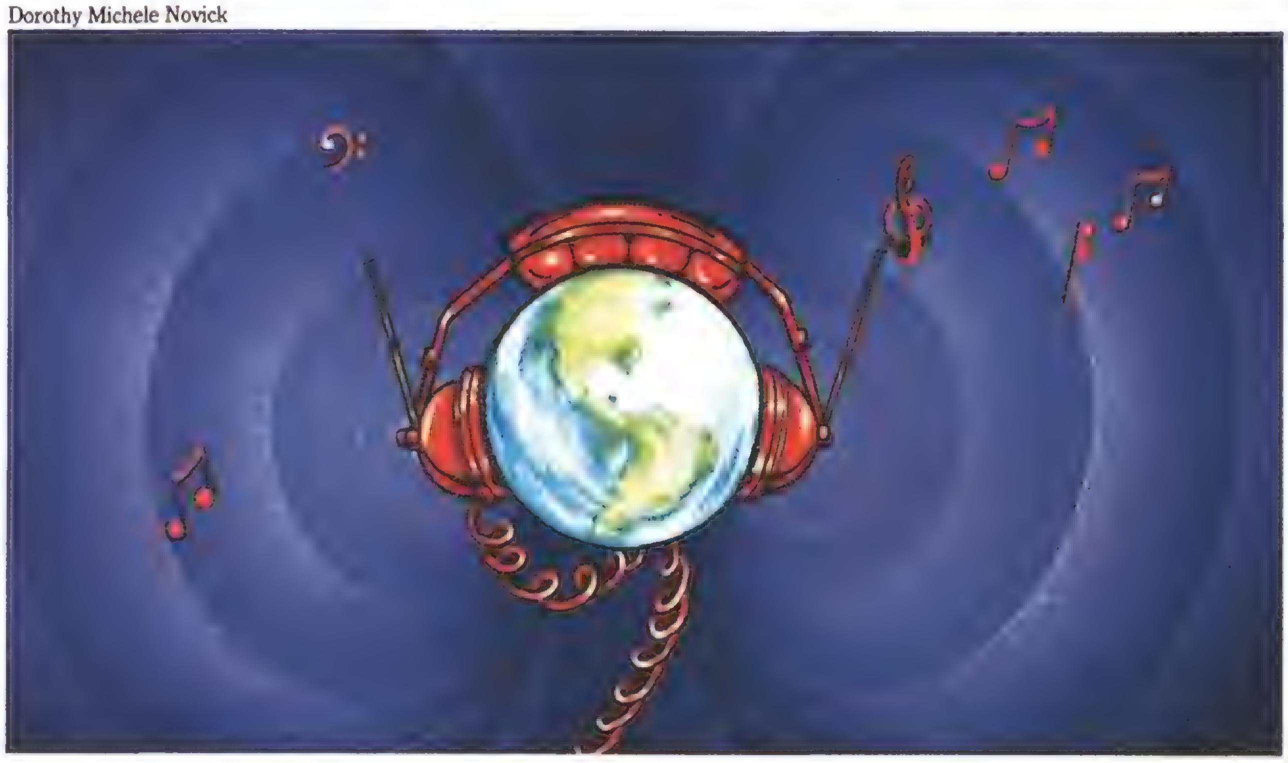
Today, the Earth's whistler capital is Siple Station, Antarctica. In 1973, Stanford built a research facility there, with a transmitter and a 12-mile-long antenna that sends up low-frequency radio waves and collects the cosmic refrains that return via the magnetosphere from the northern hemisphere. Specifically, the "other end" of the magnetic field lines turns out to be the northeastern United States and Canada, where regular outbursts of massive thunderstorms also cause some of the cosmic cacophony picked up at Siple.

Recent reports from Helliwell's group push at the very boundaries of physical science. The magnetosphere appears to warp and amplify radio waves in unpredictable—sometimes unbelievable—ways: the researchers send up coherent waves but get back incoherent hiss; they send up hiss but get back coherent whistles and tones; they put in a few watts of radio energy and get back millions. One transmission from Siple, Helliwell says, "turned on a series of echoes that kept bouncing back and forth for more than ten minutes." Soon the Siple antenna, parts of the Canadian electrical power grid, and magnetospheric particles far above Earth were vibrating together in massively amplified harmony.

Such amplification is like "seeing a dinosaur flying over your roof," says Helliwell. "It's extremely exciting stuff," because it is natural physics never recreated in the lab, and for which no theories exist.

Helliwell and others generate whistlers as an indirect way to study how particles streaming from the sun affect the Earth's atmosphere and disrupt electronic communications, and how plasmas behave in nature (the better to tame them in the laboratory and in nuclear fusion reactors).

Dorothy Michele Novick



The phenomenon might also allow us someday to create powerful energy waves from small inputs, Helliwell says, and to understand the basic forces at work in Earth's magnetic envelope. For now, however, as scientists strum the magnetosphere, the altered and magnified music they make remains a profound mystery.

—Janet Hopson

Cruising for Catfish

Paul Salmon

Diners at McGehee's Catfish Restaurant are sometimes startled when they glance out a window and see an airplane that's close enough to land in their french fries. But the aircraft always shoots by, touching down on a grass runway nearby.

Another planeload of hungry fliers has cruised in for dinner.

Perched on a bluff overlooking the Red River, on the outskirts of the small Oklahoma town of Marietta, McGehee's resembles any southern or midwestern joint that fries a mean catfish, a regional dish that's adored or despised: you either take catfish, or you leave it, period. But this restaurant's neighborhood extends more than 100 miles in all directions, drawing customers from Oklahoma City to the north, Amarillo, Texas, to the west, and a big contingent from the Dallas area to the south.

Good as the catfish may be, the real draw for those who like to eat on the fly is the 2,500-foot runway just up a small hill from the restaurant. "A lot of people had been asking me, 'Why not build a runway so we could fly in for catfish?' " says owner Rudolph McGehee. "I put down the runway just so people could fly in and walk right up to the door." Actually, patrons can taxi to within about 100 feet of the entrance, but on a busy Saturday night the walk is a bit longer, since 10 or 20 aircraft may have already taken the prime parking spots.

The restaurant got air-minded in the summer of 1981. With the guidance of some aviator friends, McGehee leveled a 30-foot hill to create the private runway, even burying the wires that provide lights for night landings. With an airport so handy, the 63-year-old McGehee has since learned to fly, and has logged about 900 hours. He now owns a Piper Saratoga and a Cessna 172 "for fun" and a helicopter for debugging his pecan trees.

Most patrons arrive by car, but the restaurant's reputation has grown among the flying community. The small airport appears at the northern edge of the Dallas sectional map, a "road map" used by pilots, but McGehee regulars will simply tell you to fly along Interstate 35, which connects Dallas and Oklahoma City, and look for the runway just east of where the highway cuts over the Red River.

The strip is a little short for twin-engine aircraft. "I'd like to stretch it out to 3,300 feet," says McGehee, "but the lady at the other end won't sell or lease me the land." He says the sod strip dries out quickly after the frequent summer rains, but he doesn't recommend landing if there's snow, which usually falls once or twice a year.

"If I'm going to go flying, and I'm hungry, I'd just as soon go to McGehee's," says Bill Davenport, a pilot from Fort Worth who makes the 90-mile flight about once a month. "It's the only restaurant around here that you can fly right up to." His single-engine Cessna can make the journey in 45 minutes with a round-trip fuel bill of about $20.

Perry Nettles flies up from the Dallas area about twice a month. He grumbles that the runway has a hump in the middle, a tricky crosswind, and no overrun in case of mistakes. But landing, he accedes, "is not a problem for most small airplanes."

Whether they fly or drive to McGehee's, diners usually order the "special"—catfish, hush puppies, cole slaw, and french fries, $7.95. McGehee's younger brother runs the kitchen, using what he says are family recipes. The semi-fileted catfish, coated with cornmeal before being deep-fried in peanut oil, turns out sweet and crisp.

The restaurant serves up 3,000 pounds of catfish a week, not bad for a place opened 12 years ago as a sideline to McGehee's catfish farm. These days, his 170 acres of ponds can supply only ten percent of the restaurant's needs. The rest of the fish comes in from Mississippi by truck.

"The fish farm helps draw people to the restaurant," says McGehee. And, too, the huge ponds double as signposts for pilots on a catfish-and-cole-slaw mission.

—Mitchel Zoler

Volcanic Island Smolders Anew

Life is usually peaceful on Miyake-jima, a tiny windswept volcanic island 100 miles south of Tokyo. Residents earn their living by fishing, growing crops, and catering to tourists, who delight in the island's gray sand beaches, winding forest trails, and 220 species of birds.

But the island, a national park, is now a political hot spot. The Japanese government is bent on building a 6,500-foot runway there, one end of which would cross a 200-yard-wide steam vent created when the island's volcano, Oyama, erupted in 1983.

The proposed runway would be used primarily by U.S. Navy pilots assigned to aircraft carriers based at Atsugi Air Base west of Tokyo. When, for example, the *Midway* is at sea, its fighter pilots can practice land-

ings around the clock, disturbing only the denizens of the deep. But in port, noise complaints from local residents have restricted the hours and frequency of practice flights, particularly at night.

For years, Japan has been promising Washington a new place to practice. Now government officials claim that Miyake-jima is the ideal site. Land is the rarest commodity in Japan, and the government maintains that Miyake-jima, active volcano notwithstanding, is the only land available close enough to the carriers' port and where so few people would be affected.

It is no great surprise that most of the 4,300 residents of Miyake-jima oppose the project, to be financed and implemented not by the U.S. government but by the Japanese. They voice their objections with a refusal to compromise rarely seen in Japan. Inn owners fear that tourists would stay home, fishermen say the fish would move elsewhere, ecologists insist that rare coral reefs around the six-mile-long island would be spoiled by construction runoff. "The entire island would feel the effects," says Mayor Haruo Terasawa.

There are, however, a few residents who welcome the runway project. They hold that the noise would be tolerable, limited to one night in four and affecting only one side of the island. Far from strangling the tourist trade, they say, the runway would open Miyake-jima to passenger jets, which the island's current airport cannot accommodate. And they welcome the $44 million in development projects that the government has offered to sweeten the deal and give the island's waning economy a boost.

However, a sturdy constitution is required to hold such views on Miyake-jima today. Emotions are at such a pitch that runway proponents can find boycotts crippling their business while childhood friends shun them on the street. Islander Noboru Kikuchi says revenues at his restaurant were down by half this spring because taxi drivers and hoteliers stopped recommending it. The reason, he says, is because he is viewed as pro-runway. Ceremonies that once brought islanders together are now tests of loyalty. Earlier this year, an elderly islander died, and her pro-runway family, rather than risk having no one show up at an island ceremony, held the cremation in Tokyo. "Since the day the gods made this land," says Tsugio Miura, a hotel operator and runway opponent, "this is the first time we have been divided."

Most islanders now refuse even to talk to government lobbyists. The government views solving the Navy's night-landing problem as essential to good military relations with the United States. But in a general election in July, the islanders showed the ruling party what they think of such reasoning. The Liberal Democratic Party was re-elected by a country-wide landslide, but locally, the party's candidate trailed as a poor third. If the government rolls over the islanders and starts building the runway, some observers say there may be demonstrations and perhaps even guerilla attacks like those that plagued Tokyo International Airport at Narita for a decade.

Though some call the runway the first step towards a permanent U.S. base on the island, most islanders say that anti-Americanism plays no role in the battle. Indeed, the United States has taken no official position on the selection of the island, saying it is a Japanese project. A Miyake-jima farmer, whose land would be seized for the project, sums up the opinion of most islanders: "It's simply a problem of airplanes."

—*John Burgess*

Leave the Flying To Greyhound

You can take a Greyhound bus from Memphis to Columbia, Mississippi, Fayetteville, Arkansas, Paducah, Kentucky, and Muscle Shoals, Alabama.

Bet you didn't know that you can take a Greyhound *airplane* to the same towns.

Suffering from severe competition with low airfares, the nation's largest bus company is now yapping at the heels of its adversaries: Greyhound is in the airplane business itself, leasing jets to the same airlines with which it competes. The company owns 35 airplanes—including Boeing 747s and 727s, McDonnell Douglas DC-9s, and Lockheed L-1011s—and leases to Pan American, TWA, USAir, Republic, America West, and faraway Air Gabon in western Africa.

According to Robert Bertrand, president and chief executive officer of Greyhound Leasing Corporation, the company invested as much as $100 million in airplanes last year. "The aircraft deals make a very reasonable return for us," he says modestly.

But don't expect to find obvious signs of Greyhound's ownership of the aircraft. You won't see the company's logo become a sleek Hound-of-the-Buskervilles racing across a fuselage. The company is more subtle: every engine on a Greyhound airplane carries a small brass plaque denoting ownership, and the postcard-sized certificate of registration hangs in each cockpit.

Greyhound isn't the only non-aviation company that leases airplanes to airlines. General Electric's fleet of large jets rivals that of TWA. Other corporate behemoths that lease on the side include Chrysler, General Motors, Ford, Xerox, IBM, Westinghouse, and Merrill Lynch. Dart & Kraft Inc.—better known for cheese, Duracell batteries, and Tupperware—owns a McDonnell Douglas MD-80, DC-10, and a Boeing 727.

Lessors fill a pressing need for the airlines. Some cash-conscious carriers lease a large portion of their fleets—TWA leases 42 of its 165 airplanes; American leases 120 of its 295; and Western leases half of its 82 aircraft. "Cash-short airlines, sky-high aircraft prices, razor-thin profit margins, and hungry manufacturers all contribute to leasing's being the preferred way to finance new airplanes," says Mort Beyer,

Paul Salmon

president of Avmark, a worldwide aviation marketing and management service.

Both the lessors and the lessees benefit from such an arrangement. For leasing companies such as Greyhound, it's a way to shelter income from taxes. The airlines lease rather than buy to reduce or avoid massive cash investments—leasing generally halves the monthly payments for financing. Some new airlines lack the credit required to buy and are forced to lease.

Though Greyhound currently limits the aircraft investments in its leasing portfolio, business has become so lucrative that those investments may increase. "If the quality of the credit is good," says Bertrand, "we plan to do as much leasing as we can."

So the next time you fly, ask if it's a Greyhound airplane. But don't worry—bus drivers don't come as part of the deal.

—Robert Dallos

You-Can't-Miss-It Department

The Federal Aviation Administration (FAA) recently modified air traffic control areas at several airports and mailed new airspace "maps" to pilots in the regions served by the airports affected. The new one-sentence description of the airspace at Washington-Dulles International Airport near Washington, D.C., follows:

"That airspace extending upward from the surface to and including 4,300 feet MSL within a 5-mile radius of the Dulles International Airport (lat. 38 56'39"N., long. 77 27'26"W.) and lying west of a line extending from the 048 bearing from the airport on the 5-mile arc to the 130 bearing from the airport on the 5-mile arc, and upward from the surface to 3,000 feet MSL east of that line, and that airspace extending upward from 1,700 feet MSL to and including 4,300 feet MSL within a 10-mile radius of the airport from the 149 bearing from the airport clockwise to the 038 bearing from the airport, excluding that airspace beyond 8 miles between the 234 bearing from the airport clockwise to the 272 bearing from the airport, and that airspace extending upward from 1,700 feet MSL upward to and including 3,000 feet MSL within a 10-mile radius of the airport from the 038 bearing from the airport clockwise to the 149 bearing from the airport, exluding that airspace east of the west boundary of the Washington, DC Terminal Control Area."

Watch for signs, and have a nice day.

—Patricia Trenner

Dorothy Michele Novick

Nott's Landing

WANTED: experienced adventurer with technical background (preferably scientific) and photographic skills (preferably movie cameras). Short tenure, some risk. Apply to J. Nott, London, England.

Balloonist Julian Nott needs a navigator to accompany him on the first manned nonstop around-the-world balloon flight. Here at the venerable Explorer's Club in New York City, where supporters and the press have gathered for the christening of the balloon's gondola, he is detailing plans for the *Endeavour*'s journey.

Next March, in this 75-pound cabin tethered beneath a helium balloon, Nott plans to head eastward from Perth, Australia, and keep going for 25,000 miles. The 42-year-old engineer and consultant has already broken 96 world ballooning records and holds a world record for a hot-air balloon ascent (55,136 feet in 1980). On this gray and humid July day, in the richly paneled Clark Room, with its decorous world map marking Club expedition sites, Nott lays out his latest plan in an impeccable British accent. The 16-day flight will follow a course about 30 degrees south of the equator, approximating the route of Captain James Cook, who completed his journey aboard the H.M.S. *Endeavour* in 1771. The record-seeker will receive no in-flight assistance from either the ground or the air.

In an age of diminishing "firsts," attendees wonder aloud why this accomplishment is so long in the making. Many have tried and failed for want of sufficient technology and materials, Nott replies. The *Endeavour*—which some liken to an Apollo capsule, but with three times the space per person—overcomes these obstacles, he says. Constructed of high-strength, lightweight laminated Kevlar, the pressurized cabin will maintain its own oxygen-rich atmosphere. By riding the jet stream at 38,000 feet, the flight should be spared any premature landings.

Financial support appears to be in place, with Australian mining magnate Ron Wise footing the bulk of the bill. Rolex USA is ensuring that the crew will always know the correct time, and the National Air and Space Museum plans an exhibit that will follow the progress of the *Endeavour.* True to tradition, the Museum has asked Nott to transfer the gondola to its collection when the flight is completed.

Don Lopez, the Museum's deputy director, speaks before the gondola is unveiled. "It's a real pleasure to represent the Museum," he says, "and this pleasure is not diminished by the fact that Julian Nott persists in misspelling the word 'endeavor.' "

Can You Build the Wright Flyer?

Many tried and failed, but Orville and Wilbur Wright built the first successful aircraft. That famous flight at Kitty Hawk, North Carolina in 1903 was big news to a world that had never before seen a piloted, gas powered airplane.

Chances are you would have had a tough time building the Wright Flyer in 1903. But now you can build a realistic 1:16 scale model of that historic plane. And, unlike Wilbur and Orville, you won't have to spend a lot of time experimenting with gliders and bi-planes. The kit by Hasegawa of Japan is so easy, even a beginner can build it!

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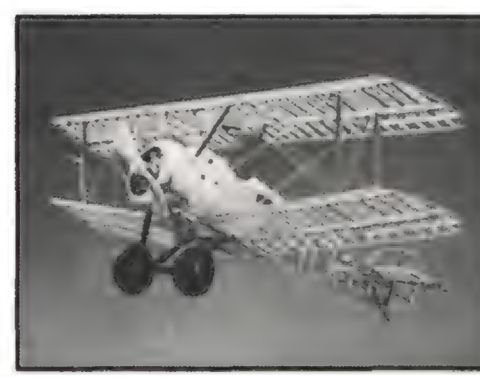

Fokker DR1 Triplane WWI Fighter

In the hands of German aces like Werner Voss, Ernst Udet and the Red Baron, the Fokker Triplane was devastatingly efficient. The Hasegawa kit features a realistic Le Rhone 110 hp engine and a pair of Spandau machine guns. 857 parts.

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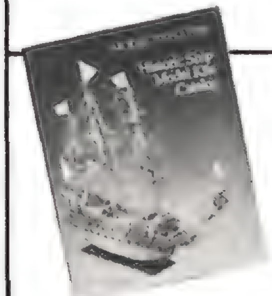

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Nott laughs when queried, and says, "James Cook spelled his ship's name with an 'o-u-r.' I didn't have a choice!"

On the veranda, publishing baron Malcolm Forbes cautiously christens the *Endeavour* with a bottle of champagne, and is asked if he has the ambition to be navigator on the flight. "No," replies the 67-year-old balloonist, "but you could say I have the ambition to *have been* the navigator."

What dangers can the navigator and Nott expect? "It's always the things you haven't thought of," says Nott, who goes on to detail the state-of-the-art navigation, communications, and survival equipment to be carried. Clearly, there isn't much he hasn't considered—unless it is the flight of the ceremonial bouquet of balloons that, when snipped free, rises skyward, straight into the branches of a tree.

—Philip Hayward

Recycling Cans at $100,000 Each

On each and every flight, the space shuttle carries 34 tons of high-grade aluminum and steel into space—then throws it away. The wasted metal is lost in the form of the large external tank (ET) that supplies liquid hydrogen and oxygen to the orbiter's main engines during liftoff. Once the ET has done its job, the orbiter jettisons the tank, which

Dorothy Michele Novick

disintegrates on re-entry, a gigantic version of "no deposit, no return."

Since the ET is not discarded until the shuttle is just short of orbital velocity, saving a tank would simply mean leaving it connected to the shuttle as it continues into orbit. Although the National Aeronautics and Space Administration (NASA) and the Department of Defense have been studying a second-generation space transportation system that would not use external tanks, the United States will probably rely heavily on the shuttle until at least the turn of the century. The challenge of "mining" the potential wealth of rescued ETs in orbit has spawned schemes at NASA and private companies to use the tanks either in their present form or as raw material for space manufacturing.

One of several recycling ideas that Wyle Laboratories of Huntsville, Alabama, has studied for NASA is melting the tanks in an orbiting solar-concentrator furnace to make parts for space structures, including the space station now planned for the 1990s. The 300-kilowatt furnace, presently only a concept, would convert ETs into aluminum stock that could then be fabricated into virtually any shape. An excellent conductor of electricity, the aluminum could even be formed into cables to deliver surplus power from the furnace to the space station or other space-based manufacturing facilities.

Of course, an ET could be quite useful in its present form. "We are looking at it as a storage container for propellants or payloads on orbit," says David L. Christensen, manager of advanced technology programs at Wyle. A plan for an orbiting filling station for "space tugs," devised at NASA's Marshall Space Flight Center, would locate crew quarters in the 19,000 cubic feet of the ET's empty oxygen chamber and a hangar in the 75,000-cubic-foot hydrogen chamber.

By the mid-1990s, a used ET could house a large gamma ray telescope now under study by NASA and the Harvard-Smithsonian Astrophysical Observatory in Cambridge, Massachusetts. According to Harvard-Smithsonian astrophysicist David Koch, astronauts would unbolt hatches in the ET, insert the detecting equipment, reseal the tank, and pressurize it to about one quarter of the Earth's atmosphere. "The gamma rays would go right through the wall of the tank, which has an average thickness of about one tenth of an inch," says Koch. Gamma rays passing through the pressurized tank would emit Cerenkov radiation, the electromagnetic equivalent of a sonic boom, revealing information about gamma ray sources such as pulsars. Since it would not be limited to the dimensions of the shuttle's payload bay, the telescope's collecting area could be 40 times that of NASA's Gamma Ray Observatory, now nearing final construction.

Another proposal is to modify one of the 28-foot-diameter, 15-story ETs into some sort of space habitat. (Indeed, Skylab, the first U.S. space station, was nothing more than an unused Saturn 5 upper-stage fuel tank outfitted with living areas and work space.) Perhaps the most practical use would be to provide welcome elbowroom for a space station crew. An ET "rec room" added to the proposed array of small space-station modules appeals to NASA planners, who recall the "Skylab 500," when astronauts on one mission raced around their orbiting home's cylindrical hull like mice in a wheel, managing to combine exercise with good old-fashioned fun. Using the much larger space inside an empty ET might provide a similar morale boost and allow longer missions. "The space station has only a few viewing ports, so a nice picture window would be great" in an ET habitat, says Christensen.

A recent report from the National Commission on Space proposes that the United States take a serious look at saving ETs, declaring, "We feel that so great a resource cannot be ignored." The commission found that the shuttle program would discard about 10,000 tons of tankage over a decade; this "payload" would cost $35 billion to lift into orbit at shuttle launch fees.

The commission's major concern is not getting the tanks up but keeping them up. "You have to tether them together and maintain them in orbit so they don't come down unexpectedly," says Paine. The expense of riding herd on a flock of tanks will only make sense, though, as part of an aggressive plan for NASA's future. The decision to recycle ETs will be made, says Paine, according to "how bullish or bearish we are about the future of the program."

—Randall Black

Manhattan Transfer

Seventy-eight million passengers bullied their way through LaGuardia, Kennedy, and Newark airports last year—and all 78 million probably seemed to be there when you were. But if you think the crowds are bad now, just wait a few years. By 1995, the number of passengers will increase to 115 million, predicts Robert Aaronson, director of aviation for the Port Authority of New York and New Jersey, the agency that manages the three airports.

It is doubtful whether the airports can handle the increase. "At peak periods, there is already congestion in the air, at the airports, and on the highways to and from them," Aaronson says, "and it can only be expected to get worse." This means more pushing and shoving, delays, and angry passengers. The skies—or at least the airports that serve them—don't seem so friendly.

The Port Authority is looking for solutions and Aaronson believes one is just over the horizon: "The tilt-rotor could provide short-haul flights from city center to city center, allowing for a substantial increase in the region's air-traffic capacity."

The tilt-rotor is a hybrid helicopter-


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Dorothy Michele Novick

airplane developed by the Army, NASA, and Bell Helicopter Textron. Called the XV-15, it looks like a conventional airplane but has engine pods on each wing tip that can be tilted from horizontal to vertical, or vice versa, in 12 seconds. When the aircraft takes off or lands, the engines and their huge rotor blades point up, and the aircraft flies like a helicopter. In flight, the pods tilt forward, the rotors act as propellers, and the aircraft flies like an airplane, reaching speeds of 340 mph, twice the speed of most helicopters.

The tilt-rotor therefore provides the speed, comfort, and fuel efficiency of an airplane and the ability to take off, hover, and land in confined areas like a helicopter. These qualities make the tilt-rotor an ideal candidate for city-to-city flights in the densely populated Northeast. Aaronson estimates that among the hordes of passengers transiting New York area airports last year, 18 million were bound for destinations easily within a one-hour tilt-rotor flight. "Within the two-hour range of 700 miles," he adds, "the number of passengers increases to 26 million." Other officials estimate that the short-haul market at some air hubs could be as high as 30 percent.

"Imagine taking off from downtown Washington and arriving 45 minutes later in downtown Manhattan," says Raymond Colladay, associate administrator at NASA's Aeronautics and Space Technology division. "Such a trip now can take several hours, if you include the time spent getting to and from congested or remote airports."

Port Authority officials foresee tilt-rotor "shuttle ports" on the region's waterfront, with approaches and departures over water providing maximum safety and a minimum of noise for neighbors. Passengers could use subways and buses rather than taxis and limousine service as ground transportation. The tilt-rotor experiences a minimum of vibration, and is expected to create less noise—and have fewer maintenance problems—than helicopters.

But before the tilt-rotor can revolutionize regional air transportation, a commercial version has to be built. Two XV-15s have been flying for almost ten years as demonstrators for the military, but no prototype airliner version exists. In May, the Pentagon awarded a contract to the team of Bell and Boeing Vertol for six prototype V-22 Osprey tilt-rotor aircraft. The Army, Navy, Air Force, and Marine Corps have plans for more than 1,200 of the 24-seat Ospreys, which will result in contracts worth $25 to $40 billion, depending on who you talk to at the Pentagon.

The Osprey's first flight is scheduled for June 1988, with deliveries to the Marines to begin in December 1991. The aircraft will be used for a wide range of missions, including combat assault and support, search and rescue, and anti-submarine warfare.

The Port Authority hopes, not unrealistically, that a 40-seat commercial version of the Osprey will be developed along with the military aircraft. Both Bell and Boeing recognize the sales potential of such a spin-off. According to Joe Mallen, president of Boeing Vertol, "Tilt-rotor aircraft will play a major evolutionary role in the continuing development of air transportation, beginning as early as the mid-1990s."

The Port Authority has authorized a feasibility study on the use of the tilt-rotor to meet regional needs, and NASA, the Federal Aviation Administration (FAA), and the Department of Defense have agreed to study the national benefits. According to Colladay, the studies will evaluate the commercial tilt-rotor market, optimum aircraft design, development of ground facilities, and the certification process—this new breed does not fit FAA definitions for either an airplane or a helicopter. "But it could all happen within five to 10 years," says Colladay.

Until then, millions of passengers each year will just have to grin and bear it. Then again, there's always the train.

—Steve Wartenberg

Update

The Vandenberg shuttle facility ("Spaceport West," April/May) will be put into "operational caretaker" status for at least six years, says Air Force Secretary Edward Aldridge, saving taxpayers approximately $1 billion. However, that savings will probably be eaten up by an unmanned launch program. If budget requests receive congressional approval, military launches will be via Titan 2 and new Titan 4 rockets, which can carry payloads equivalent to those of the shuttle, and a medium-lift vehicle that has not yet been designated. "We made a mistake deciding that the shuttle would be our exclusive space launch system," says Aldridge, "and we're paying the price now." The cost of the unmanned program is estimated at $2.6 billion.

The superstring theory ("Groundling's Notebook," April/May) and its supporters are under attack by Yale physicist Alan Chados, who believes that "faddish" particle physicists may be tempted to embrace untestable theories such as "this Holy Grail of the Ultimate Theory," in Chados' words. He says that physicists, deprived of tangible experimentation, will "wander off into uncharted regions of philosophy and pure mathematics," a practice that he warns could again lead science into blind alleys and mysticism.

Inadequate wind shear information and guidelines for pilots caught in microbursts were probable causes in the August 1985 crash of Delta flight 191 ("The Might of the Microburst," August/September), according to an investigation by the National Transportation Safety Board. The Board recommended that the Federal Aviation Administration improve its wind shear reporting system and strengthen warnings to pilots to avoid thunderstorms.

A microburst has also been implicated in the sinking of the *Pride of Baltimore* off the coast of Puerto Rico in May. Four of the crew drowned when the replica of a nineteenth-century schooner sank during a "white squall," a high wind unaccompanied by the dark storm clouds normally present in a squall. "You could not look into the

wind, it was so strong," deck hand Dan Krachuck reported. Raymond Biedinger, a broadcaster with the National Weather Service, later testified at a Coast Guard inquiry that the hurricane-force winds, according to the crew members' description, "had all the indications of a microburst."

Monsignor James Horan, the driving force behind Knock Regional Airport in Ireland ("Wings and a Prayer," August/September), died of a heart attack on August 1 at age 75. He had just completed the annual pilgrimage from his diocese to Lourdes when he was stricken.

Beryl Markham, British aviation pioneer and author of *"West With The Night,"* ("Moments and Milestones," June/July), died August 3 in Nairobi at the age of 83, after surgery for a leg fracture.

The H-1 satellite launcher ("Soundings," August/September), Japan's upgraded version of the U.S. Delta rocket, is under scrutiny by McDonnell Douglas, which builds Deltas for NASA, for its performance upgrades. Of particular interest is the LE-5 liquid-fuel second-stage engine. McDonnell Douglas is talking with Japanese space officials about transferring LE-5 technology to the United States in order to make bigger and better Deltas. The United States originally transferred the Delta design to Japan, where it became known as the N rocket. McDonnell Douglas also is eyeing the larger H-2 rocket, of all-Japanese design, to be operational in the 1990s.

An experimental blimp ("Picture Your Ad Here," April/May) crashed at Lakehurst Naval Air Station in New Jersey on July 1, killing a crew member and ending U.S. Forest Service support for the project. The 343-foot-long helium-filled Heli-Stat, with four Sikorsky helicopters at the aft end, was built by Piasecki Aircraft for logging operations. The Forest Service is now investigating the use of an AeroLift CycloCrane, another ultra-heavy-lift aircraft that has been flying since 1982 in a program supported mainly by Canadian forest product companies.

The Celestis Group ("Dollars from Heaven," June/July), which plans to launch "cremains" into orbit, has been charged by the Florida State Comptroller with violating laws requiring at least 15 acres of land for a cemetery, accessible by paved road. "We're a transportation company, not a cemetery," says company president Jim Kuhl. "We move cremains from here to there, just like an airline or any other form of transportation." A hearing is set for mid-October.

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Hello? Hello?

Wee Bonnie Baker, a song stylist of days gone by, recorded a number in 1949 whose lyrics went: "I've been waitin' for your phone call for eighteen years. Maybe you don't love me anymore."

Astronomers at Harvard and Ohio State Universities ought to be echoing Bonnie's sentiments about now. They're the main listening posts in the search for extraterrestrial intelligence, or SETI. If there are intelligent creatures somewhere in space, maybe they don't love *us*. Still, you'd think at least one alien would be courteous enough to call, or mad enough to write a complaint letter about the bad rap aliens have been getting in Hollywood lately.

The space mavens believe our galaxy serves as host to more than a hundred million planetary systems—though they've never actually seen one—and there may be zillions of other galaxies. Astrochemists also say the building blocks that contribute to living matter—such as carbon, hydrogen, water, and methane—are adrift in the cosmic sea. Energy from a lightning bolt, say, could transform the molecules into microbes and such. You know the rest of the story. Two and a half billion years later, they'll invent sex. That's life.

The basis for SETI rests on the probability that thinking beings will be created in the process of evolution. Nobody's sure, mind you. Carl Sagan doesn't *really* know. And he can't phone Jimmy the Greek to learn the odds: Jimmy's only interested in cosmic forces if they affect the National Football League play-offs.

Another article of faith in this business is that ETs would try to communicate with us via radio frequencies. For sure, the heavens aren't a quiet place—they're rocking and rolling with static that intrudes on most of the radio spectrum. It's the everyday music of the cosmic chorus, emanating from such sources as the Big Bang, quasars, and newly discovered curiosities called noisars. Plus maybe a little extra static from the ignition of an occasional passing truck.

But certain slices of the microwave spectrum are not only relatively free of Martian Muzak and Jovian Jazz; they are also "magic" frequencies that would clearly be best for interstellar communication. One such frequency is emitted by hydrogen atoms, the simplest and most abundant atoms in the universe, which makes it a cosmological lingua franca. Then there is the spectral region between hydrogen and hydroxyl, a molecule containing one hydrogen and one oxygen atom. Since hydrogen and hydroxyl are decomposition products of water, scientists have dubbed this region the "water hole," and they hope galactic species might mingle here just as animals seek water holes on Earth.

Astronomer Frank Drake eavesdropped at the water hole in 1960 when he ran Project Ozma—named after Dorothy's adventures in Oz—at the National Radio Telescope Observatory in Green Bank, West Virginia. He garnered nary a whisper from any alien beings that may reside in the vicinity of Epsilon Eridani or Tau Ceti, two stars a mere 11 light-years from the sun.

But Drake's equipment was primitive and could scan only a few channels at a time. Indeed, this remained a major technological problem for astronomers until a half-dozen years ago. Enter Paul Horowitz, a Harvard physicist who designed a device that can scan 128,000 frequencies at once. So compact that even a tired scientist could schlep the device around, it became known as "suitcase SETI."

Horowitz' restless mind soon conjured up an even better idea. He hooked 144 computers to the university's 84-foot radio telescope. This "megachannel extraterrestrial assay," or META, started scanning the skies late last year. The new equipment won't fit into your favorite valise—it sports 25,000 microchips and a half-million hand-soldered joints—but it increases the number of frequencies that can be monitored at one time to 8.4 million.

Libby Thiel

But the best is yet to come. The National Aeronautics and Space Administration will join the search in a big way in the 1990s, using the antennas of the Deep Space Tracking Network and securing the cooperation of major observatories throughout the world.

Maybe the new facilities will help. But there could still be problems. Perhaps the ETs are procrastinating types who live only for today, while getting a message to us could take hundreds of centuries. In fact, Earth sent a radio signal once to a cluster of stars known as Messier-13 and we're still waiting for an answer. Of course, it will take that signal a while to reach its addressee. A good while, you might even say—about 24,000 years. Some scientists offer a simpler explanation for the silence: our extraterrestrial neighbors probably don't think that communicating with us is worth the bother.

Maybe. But I'll bet that, somewhere out there, galactic brainstorming sessions are taking place in an effort to find something to say to us earthlings. After all, it's widely agreed that many space beings are probably eons ahead of us in intelligence, so they've got to come up with something more profound than "Have a nice day!"

If you're really there, ETs, why don't you reach out and touch the astronomers at Harvard or Ohio State? At the very least, you could give them a little encouragement—maybe a garbled message. Just something to brighten the celestial highway as they drive onward through the light-years of space debris, listening to rumblings of the cosmic stomach on their radios.

If not, as Wee Bonnie warbled: "I'll wait for your phone call for eighteen more. But, after that, we're through."

—*Phil Cohan*

Anniversaries and Events

1783
November 21 François Pilatre de Rozier and François Laurent, the Marquis d'Arlandes, become the world's first aeronauts in a 25-minute flight in a Montgolfier hot-air balloon. The five-mile flight, witnessed by all of Paris, including visiting diplomat Benjamin Franklin, was originally to be made by criminals, who would be pardoned if they survived. Incensed that King Louis XVI would give felons the glory of being the first aloft, de Rozier offered his services as a passenger and won the right to make the flight—with the Marquis in tow.

1907
October 1 Dr. Alexander Graham Bell, with Glenn Curtiss, forms the Aerial Experiment Association at the suggestion of Mrs. Bell, who funded the organization's efforts until its demise in March 1909.

1910
October 15 The wealthy and adventurous American journalist Walter Wellman departs Atlantic City, New Jersey, in the hydrogen dirigible *America* to cross the North Atlantic. Three days later, Wellman and his crew of five—plus a cat named Kiddo—are rescued off the New England coast by the British ship *RMS Trent* after engine problems ended the flight.

1929
October 8 The first in-flight motion pictures—two cartoons and a newsreel—are shown aboard a Transcontinental Air Ford Transport cruising at 5,000 feet.

1933
October 5 Eastern Air Transport introduces sleeping berths on a Curtiss-Wright Condor. The first passenger to partake of such luxury is Captain Edward Rickenbacker, on the Atlanta-New York run.

1938
October 30 The young Orson Welles narrates the Mercury Players' broadcast of Howard Koch's "Invasion from Mars," adapted from H.G. Wells' "War of the Worlds" as part of a series of radio dramas based on famous novels. A minor panic, evacuation, and traffic jam ensued when residents of New York and New Jersey who missed the radio introduction believed that Martians were actually landing near Trenton. As to why so many people misinterpreted the Halloween joke, one observer suggested that "all the intelligent people were listening to Charlie McCarthy."

Halloween, 1938: Listeners could either choose Orson Welles' "War of the Worlds," and panic . . .

AP/Wide World Photos

. . . or tune in their radios to catch Charlie McCarthy and Edgar Bergen's less threatening verbal jousts.

1946
November 13 Vincent J. Schaefer of the General Electric Company produces artificial snow by seeding a cloud at 14,000 feet over Mt. Greylock in Massachusetts with dry-ice pellets. Snow fell 3,000 feet but evaporated before reaching the ground.

1947
October 14 Captain Charles Elwood Yeager exceeds the speed of sound in the Bell XS-1 over the Mojave Desert. Yeager reached Mach 1.06—700 mph—at 43,000 feet, producing the first recorded sonic boom. The achievement was kept secret by the Air Force for eight months. In 1968, the Man Will Never Fly Memorial Society awarded Yeager the Anti-Aviation Hall of Infamy award for "being clumsy enough to break the sound barrier."

November 2 During taxi tests, Howard Robard Hughes makes an unscheduled one-time flight in his H-4 Hercules, the largest flying boat ever built, for one minute over Long Beach Harbor (near Los Angeles) at an altitude of 70 feet. The wooden "Spruce Goose"—a name coined by the press and abhorred by Hughes—had eight engines on its 320-foot wingspan and was designed as a cargo ship. Today it is housed in a 700-foot-diameter dome next to the *Queen Mary* in Long Beach.

1957
October 4 The world's first artificial satellite is launched from the Baikonur Cosmodrome in the Soviet Union. *Sputnik 1* ("traveler") orbited the Earth at altitudes between 155 and 560 miles for 21 days. The 23-inch, 184-pound satellite collected data on the electrostatic field, cosmic rays, and the composition of the ionosphere, and demonstrated radio communications from

space with a continuous sequence of beeps, which became an audio symbol of the space race that followed.

1958
October 1 The National Aeronautics and Space Administration—NASA—is established to define and oversee civil space programs in what was largely a catch-up reaction to the success of *Sputnik*.

1960
November 9 The U.S. Postal Service demonstrates the feasibility of "speed mail" by sending a letter in the form of microwave signals from Washington, D.C., to Newark, New Jersey, via the reflective surface of the 100-foot-wide *Echo 1* plastic satellite, which resembled a giant balloon.

1963
October 17 The 18th session of the United Nations General Assembly passes resolution no. 1884, preventing the placing of weapons in space. This confirmed an earlier resolution that space development would be for peaceful purposes only.

1967
October 3 U.S. Air Force Major William J. Knight flies the North American Aviation X-15A-2 at 4,534 mph, or Mach 6.72. The X-15 bridged the gap between manned atmospheric and space flight, and set speed and altitude records (67 miles) that still stand today. The X-15 program ended in 1968.

1971
November 24 Passenger "Dan B. Cooper" exits the rear door of a Northwest Orient Boeing 727 over southwestern Washington with $200,000 ransom in ten- and twenty-dollar bills and a parachute, all of which he demanded and received during a stopover in Seattle. It was his last public appearance. Nine years later, eight-year-old Brian Ingram found $5,800 buried in the sand of the Columbia River bank in Vancouver, Washington. Last June, Ingram, now 14, and an insurance company divided the money, which the FBI had been holding as evidence in the nation's only unsolved hijacking. Ingram hopes to sell his share to collectors to finance an education and a down payment on a farm for his parents.

AP/Wide World Photos

The buck stops here—according to FBI agents digging for D.B. Cooper's dollars.

1977
November 22 The British Airways/Air France *Concorde* lands at Kennedy International Airport in New York City after long delays caused by a group of residents who claimed the noise level would be intolerable. During the first weeks of scheduled flights, noise complaints about the *Concorde* were received when the aircraft was nowhere near the area. Today, the SST routinely flies in and out of Kennedy, noticed only for its aerodynamic aesthetics.

1984
October 2 Three Soviet cosmonauts return to Earth after a record 237 consecutive days aboard the *Salyut 7* space station. Two of these cosmonauts returned in July from a 125-day mission that included a round-trip flight via a Soyuz T-15 "space taxi" between the new *Mir* space station and the *Salyut 7* station.

Events

Through October 13
"Expo 86" World's Fair. Vancouver, British Columbia (604) 689-1986. (See page 74 for a related article.)

Through October 19
"Twenty-five Years of Manned Space Exploration" (Smithsonian Traveling Exhibition). Frankfort, Kentucky. At Kentucky State University. Blazer Library (502) 227-6852.

"Black Wings: The American Black in Aviation" (Smithsonian Traveling Exhibition). New York, New York. At Bronx Community College (212) 220-6366.

Through November 2
"Early Flight: 1900-1911" (Smithsonian Traveling Exhibition). Greensboro, North Carolina. At Greensboro Historical Museum (919) 373-2043.

Through November 8
"America's Space Truck: The Space Shuttle" (Smithsonian Traveling Exhibition). Hickory, North Carolina. At Catawba Science Center (704) 322-8169.

Through April 30
10th Annual EAA Sport Aviation Art Competition Exhibit. Oshkosh, Wisconsin. A display of 29 paintings selected from the 130 entered. At Experimental Aircraft Association Aviation Foundation, Gorman Art Gallery (414) 426-4800.

October 2
"The Ph.D Mission: Phobos and Deimos." Philadelphia, Pennsylvania. A lecture by space consultant and ex-astronaut Brian O'Leary on the proposal to land on the Martian moons. Mars Society of Philadelphia (a new organization to promote space exploration and Philadelphia's role in the space program) (215) 732-2593.

October 3
Annular-total solar eclipse. An annular—"ring-shaped"—eclipse occurs when the moon is more than 242,000 miles from Earth. At that distance, the shadow of the moon is not large enough to block out the sun entirely, and the sun appears as a ring around the disc of the moon. Partial phase visible in nearly all of North America except extreme southwest. *

October 4-11
"Space: New Opportunities for All People." Innsbruck, Austria. The 37th Annual Congress of the International Astronautical Federation. Space professionals will discuss space transportation, remote sensing, space safety and rescue, space law, and the search for extraterrestrial intelligence. Some of the lesser-known IAF members include the Bulgarian Astronautical Society, the Indian Rocket Society, and the Pakistan Space and Upper Atmosphere Research Commission, as well as U.S. and Soviet organizations. American Institute of Aeronautics and Astronautics (212) 581-4300.

October 4-12
Albuquerque International Balloon Fiesta. Albuquerque, New Mexico. More than 500 balloons are expected. Airshow including the Thunderbirds. (505) 344-3501.

October 9-10
"Winged Wonders: The Story of the Flying Wing" and *"The Golden Age of Flight."* Midland, Texas. Lecture and seminar by curators of the National Air and Space Museum. At Permian Basin Petroleum Museum. Smithsonian National Associate Program (202) 357-1350.

October 9-12
"AIRSHO 86." Harlingen, Texas. The annual Confederate Air Force airshow of World War II aircraft. At Valley International Airport. CAF (512) 425-1057.

October 10-11
Yankee Air Force Tour. Dayton and Wapakoneta, Ohio. Tour of Wright-Patterson Air Force Museum, including restora-

Peter Michael

The sun will highlight lunar peaks and valleys in the October 3 annular solar eclipse.

tion area, and Neil Armstrong Air and Space Museum. Lodging included in tour price. (313) 425-2094 or (313) 562-3283.

October 11
"The Golden Age of Flight" and *"Behind the Scenes at the National Air and Space Museum."* Lubbock, Texas. Seminars by Claudia Oakes of the National Air and Space Museum. At The Museum, Texas Tech University. Smithsonian National Associate Program (202) 357-1350.

October 12
"Interplanetary Confederation Day." El Cajon, California. According to the sponsor, the Unarius Educational Foundation, "a celebration to promote recognition of our brother planets in the Milky Way—32 worlds waiting to join ours in an Interplanetary Confederation." (619) 447-4170.

October 13-17
"Toward Space Civilization." Budapest, Hungary. The Second Planetary Congress of the Association of Space Explorers. Space flight is the only requisite for joining the association, which encourages all astronauts and cosmonauts to get acquainted, share space flight stories, and promote space exploration. ASE (415) 931-0585.

October 17
Lunar eclipse. Total eclipse of the "Hunter's Moon," the first full moon after the Harvest Moon, which provides additional light for hunters. *

October 17-19
"From the Heartland to the Heavens." Strongsville, Ohio. The second annual Midwest Space Development Conference. At Holiday Inn. MSDC (216) 282-6329.

October 18-November 16
"America's Space Truck: The Space Shuttle" (Smithsonian Traveling Exhibition). Statesboro, Georgia. At Georgia Southern Colonial Museum (912) 681-5444.

October 19
"The Golden Age of Flight." North Chicago, Illinois. Lecture by Claudia Oakes of the National Air and Space Museum. At Chicago Medical School. Smithsonian National Associate Program (202) 357-1350.

October 21
Orionid meteor shower. Two to three hours before sunrise. Light of the full moon interferes with this meteor shower, a result of the Earth crossing the orbital path of Comet Halley. *

October 25-26
Miami Airshow. Opa Locka, Florida. Celebrates the 75th anniversary of naval aviation. Blue Angels, Golden Knights. At Opa Locka airport (305) 685-7025.

October 26-29
"Aerospace:—Century Twenty-one." Boulder, Colorado. American Astronautical Society Annual Meeting. At Hilton Harvest House. AAS (703) 866-0020.

October 29-November 1
31st Annual Aircraft Owners and Pilots Association Convention and Industry Exhibit. San Antonio, Texas. Workshops, seminars, and exhibitions for the general-aviation pilot, and the Fourth Annual Great American Paper Airplane Contest for both pilots and non-pilots. At San Antonio Hilton. AOPA (301) 695-2156.

November 1-30
"Jupiter and its Moons" (Smithsonian Traveling Exhibition). Atlanta, Georgia. At Fernbank Science Center (404) 378-4311.

November 2
Virginia's Savedge Pig Pickin'. Surry, Virginia. International Flying Farmers picnic hosted by members of the Savedge family. At Melville Airport. IFF (316) 943-4234.

November 8-December 7
"Twenty-five Years of Manned Space Flight" (Smithsonian Traveling Exhibition). Indianapolis, Indiana. At Indiana State Museum (317) 232-1637.

"Black Wings: The American Black in Aviation" (Smithsonian Traveling Exhibition). Mobile, Alabama. At Battleship Memorial Park (205) 433-2703.

November 13
Transit of Mercury. The disc of Mercury will be visible against the disc of the sun for the first time since 1973. Visible in Australia, Asia, eastern Europe. *

November 14-24
"Wingding '86-An Aviation Celebration." Treasure Cay, Abaco, Bahamas. Air tours, seminars, displays, sports, socializing. At Treasure Cay Beach Hotel. (800) 327-1584; in Florida, (800) 432-8257.

November 15
Eighth Annual Chili Cook-off. Clark Air Base, Philippines. Awards for Best Chili, Best Showmanship, Ms. Local Chili Pepper, and Ms. Import Chili Pepper. At Silver Wing Recreation Center.

November 15-16
Thunderbird Balloon Race. Glendale, Arizona. More than 100 balloons are expected at a carnival with international foods, skydiving, and a petting zoo. (602) 978-7208.

November 13
"Twenty Years of Selling Space: Creating NASA's Image." Lecture by Brian Duff of the National Air and Space Museum. Fort Worth, Texas. At Fort Worth Museum of Science and History. Smithsonian National Associate Program (202) 357-1350.

November 17
Leonid meteor shower. Two to three hours before sunrise. Full moon interferes. *

November 22-December 28
"Early Flight: 1900-1911" (Smithsonian Traveling Exhibition). Lansing, Michigan. In conjunction with "Lansing in the Air" exhibit, which chronicles the city's involvement with air transportation and the aerospace industry. At R.E. Olds Museum (517) 372-0422.

** Call the Smithsonian "Earth and Space Report" for recorded information on astronomical events at (202) 357-2000.*

Organizations wishing to have events published in "Calendar" should submit them at least three months in advance to Calendar, Air & Space/Smithsonian, *Room 3401, National Air and Space Museum, Washington, DC 20560. Events will be listed as space allows.*

—*Patricia Trenner*

Star-Making Machinery

One moment there is only the white, domed ceiling of the Museum's Albert Einstein Planetarium, like half of a huge Ping-Pong ball cupping the dim auditorium. Then the lights fade, and suddenly the roof has been torn off, revealing a clear night sky exploding with stars. One can almost hear the gentle chirping of crickets, or the frosty sigh of a winter wind. With the right audio effects, one can.

A show at the planetarium is a complex audio-visual presentation, where hundreds of slide projectors peek out from beneath the rim of the dome, working with synchronized precision to create a variety of effects. Some of the projectors are much like the ones our grandparents used; others are complex machines that create moving or subtly distorted images. Stereo speakers stand behind the dome, for a narration or specially composed score.

In the center of the circular room stands the Zeiss machine, the many-eyed light projector and master of illusion that plays God by creating the sun, moon, planets, and the 8,910 stars visible to the naked eye. Its gossamer Milky Way stretches from horizon to horizon, while its visible planets take seconds for dance steps that last 24 hours or more in the real world.

A Zeiss machine can portray the heavens, but it takes human imagination to personify the constellations. Dale Hrabak

"The vast bulk of the show is slides, camouflaged in such a way that you don't know you're looking at slides," says planetarium chief James Sharp. For example, a special-effects projector can create a rotating galaxy by spinning a static image and using a special anamorphic lens to squeeze it into a more side-on view. Slides and Zeiss must be carefully synchronized to mesh not only with the soundtrack, but also with the reality of the heavens.

For their two most recent shows, last season's "Summertime" and "State of the Universe," which debuts in November, Sharp, program resource manager Tom Callen, and production coordinator Geoff Chester have been greatly aided by new computers. "It's always been computerized," Sharp says, "but the original computer—now deceased—was really overburdened. It couldn't do the tight cuing, the really precise transformations. Two years ago we replaced the part that controls the slide projectors and the special effects. This year we replaced the part that controls the Zeiss machine."

Like an electronic octopus, the computer controls every one of the hundreds of projectors, and coordinates them with the Zeiss machine. The computer's commands—the "bleeps and blorps," in Sharp's scientific jargon—are usually transferred to an ordinary audio tape to run the show. The star-making machinery never knows if the commands are real or if they're Memorex.

The most striking element in the planetarium is the Zeiss machine, which rises out of its recessed pit like a gigantic extraterrestrial bug. Inside the two soccer ball-like bulbs on each end are mercury arc lamps, which project through perforated star fields onto the dome.

The Zeiss machine has separate lights for each of the 12 brightest stars in our sky, and the planets' light sources are enclosed in separate cages along the axis of the device, attached to complex gears that mimic each orbit as viewed from Earth. The machine, which does not differ significantly from the first one constructed by Walther Bauersfeld in 1924, can also pivot around various axes to map the sky as seen from different latitudes and seasons.

A Zeiss machine is a fairly expensive piece of equipment. "If you were to go to the Zeiss company and ask to buy one, I'm sure they would cheerfully sell one to you for one to one and a half million dollars," Sharp says. The Museum, however, got a bargain—its machine was donated by the West German government as a Bicentennial present. West Germany also provided the 70-foot-diameter aluminum dome, which, despite its solid appearance, is actually perforated by some 81 million tiny holes.

The new planetarium show, "State of the Universe," has something for almost everyone—it's a "kitchen sink show," says Sharp. "We were toying with the idea of a Space Telescope show, which I now realize I wisely resisted, with the shuttle postponed until 1988," Sharp says of the instrument that was to be taken aloft by a shuttle. "Then we decided to put the Space Telescope in the context of the whole centuries-old quest for higher and higher resolution to look at this tantalizing universe."

Beginning with the ancient Babylonians and their desire to understand the origins of the universe, the show delivers a mini-course on mankind's increasingly complicated efforts to learn more. "But that gets wearing after a while," Sharp says, "so we took the folks out into the universe for a whirlwind tour." The tour includes stops along the way to discuss the various classifications of stars, the distribution of galaxies, and the mystery of quasars.

Despite the amount of information in "State of the Universe," Sharp does not believe in using the planetarium, which seats over 230 people, as a glorified lecture hall. "I think of it more as an inspirational medium than an informational one," he says. "It's difficult to teach specific facts. The audience comes out with more of an understanding and appreciation, and maybe they'll go to the library and take out a book. It inspires them to think more about the universe than when they walked in."

Sharp's puckish sense of humor may also provide a chuckle or two. In last season's "Summertime," the Zeiss machine rotated the sky in a manner not consistent with reality. "If you should see the sky move like this," the narrator intoned, "don't call us. Call the Davis Planetarium in Baltimore."

Made in Italy

In 1986, the centennial of his birth, Italy's Count Gianni Caproni di Taliedo is one of aviation's forgotten pioneers, despite his accomplishments. In 1910 his CA 1 became the first successful airplane designed and built in Italy. In 1912 a Caproni CA 9 became the first Italian airplane to carry a paying passenger. Caproni also founded the Caproni aviation school at Vizzola, which opened for business in 1911.

By the time of his death in 1957, Caproni had been responsible for the design of over 150 aircraft, including Italy's first jet airplanes, the Campini-Caproni C.C.1 and C.C.2. Perhaps part of the reason for his eclipse was the fact that he built many of his airplanes for the losing side in World War II. "At the height of his career—1943—he had 20,000 employees," says Karl Schneide of the Museum's Aeronautics department. "That's a lot for a small airplane industry."

If Schneide has his way, Caproni won't remain forgotten for long. Thanks to his persistent efforts, the Museum will install a CA 9, the first airplane ordered by the Italian government for mass-production, in the "Early Flight" gallery.

The CA 9, a delicate monoplane with a 35-horsepower engine and a 25-foot wingspan, was supplied to the Museum as a "very long-term loan" by Caproni's daughter, the Contessa Maria Fede Caproni Armani. She is in charge of the Museo Aeronautica Caproni di Taliedo, which Schneide says is probably the largest privately owned airplane museum in Europe, with a total of 52 aircraft, most of them pre-1920. One of them is the historic Caproni CA 1, which is now inside a monastery in Venegono, Italy, where the walls were con-

After a hard day's flight, a CA 9 returns to its hangar.

Museo Aeronautico Caproni Di Taliedo

structed around it, effectively sealing it off from the sky.

"On my last trip, a year ago, I pursued the idea of using Caproni's one-hundredth birthday as justification for an exhibit," says Schneide. He first suggested exhibiting the CA 1, but the Museum administration turned down the proposal. "Then I proposed the CA 9 and it was accepted. This is also the 75th anniversary of the CA 9, which is another justification for the exhibit."

Schneide flew to Italy to arrange the loan of the airplane, with assistance from General Basilio Cottone, chief of staff of the Italian Air Force, who arranged for transportation of the Caproni to the United States. The airplane was disassembled and packed, shipped by truck to Pisa, then loaded aboard an Italian Air Force C-130 for the flight to Andrews Air Force Base near Washington, D.C. It was then taken to the Museum's Garber facility for cleaning and reassembly.

"We've never had a foreign country deliver an airplane to us like this," Schneide says with delight. "It's a big deal for them. They're honored and flattered that the Smithsonian would want to do this. They've proposed an official stamp, and struck a [commemorative] medal."

Schneide believes that Italian aviation doesn't receive the credit it deserves. "There is not enough written in English to get across what they've done in aviation," he says, pointing out that Italian pilots were the first to use the airplane in war, although they flew Austrian and French machines. Italian partisan that he is, Schneide also thinks Caproni should get credit for designing the first multi-engined bomber. "The credit goes to Igor Sikorsky," he says, "but he designed the *Il'ya Muromets* as a passenger airplane, then converted it into a bomber.

"I've always loved Italian airplanes," Schneide says, pointing out that the only other Italian aircraft in the Museum is the Macchi C.202 Folgore in the "World War II" gallery. "They're beautiful. They're not efficient and they're not built to win wars, but they're beautiful."

"Star Trek" Turns Twenty

Twenty years ago this fall, the starship *Enterprise* and her crew of 430 set out on a five-year mission "to seek out new life and new civilizations." It was, alas, a mission cut short two years by television network indifference. But syndication accomplished what Nielsen ratings couldn't, and intense interest in "Star Trek" has kept the show alive and well in reruns for 17 years and on movie screens in three (soon to be four) motion pictures.

The valiant starship itself hangs in the entrance to the Museum's "Rocketry and Space Flight" gallery. Donated by Paramount Pictures in 1974, the 11-foot wood-and-plastic spaceship is the model used for the series, though only one side of it was filmed. The other side hid the wiring that ran the lights.

"Star Trek" fans take particular delight in the model. "I had one man on the phone from Denver who was ready to hop on an airplane just to see the *Enterprise*," says Janice Hill of the Museum's Space Science and Exploration department. "He was building a model and wanted to be accurate."

What Trekkies may not know is that the Museum's collection includes more "Star Trek" spaceships in storage. The Museum also owns the model of the Klingon battlecruiser *(hiss)*, the alien ship from the "Tholian Webb" episode, and the small steel *Enterprise* embedded in clear plastic

Boldly going where no man has gone before.

Robert McCall

from the "Catspaw" outing.

"Star Trek" fans have a knack for getting recognition of their favorite show. The space shuttle prototype, now owned by the Museum (see "In the Museum," April/May) was named *Enterprise* after a spirited write-in campaign, and they recently just missed getting a new television series. Now they are petitioning for a "Star Trek" postage stamp. According to Hill, there was talk of a write-in effort to persuade the Smithsonian Institution to create a display for the show's 20th birthday, but tight exhibit schedules doomed any such attempt from the start.

The series' fans can look to the future, when the Museum will dust off its complete collection of "Star Trek" paraphernalia, including some lovable tribbles and a series of Robert McCall paintings, for a small exhibit commemorating the show's 25th anniversary. That will be in 1991—Trekkies, mark your calendars.

License Renewed

For almost ten years it had been displayed in the National Air and Space Museum, a prospective space traveler that never left its home planet. Now most of the Oscar 17 satellite, taken out of mothballs, refurbished, and renamed, will finally make the journey for which it was intended. As part of Polar BEAR (Beacon Experiment and Auroral Research), the satellite's solar panels, main structure, and some of its electronics will be launched from Vandenberg Air Force Base in California. The satellite's experiments for the Department of Defense are designed, the Air Force says, to help its fellow satellites beat the insidious radio interference generated by the northern lights (aurora borealis).

In exchange for the Oscar 17, the Museum received a Transit 5, an almost identical but historically more important navigational satellite. The Transit 5, constructed in the early 1960s, is a back-up for the original satellites used in the historic Navy Navigation Satellite System (NAVSAT), the first use of satellites for navigation. The system became available to Navy vessels in 1964, and for commercial and oceanographic research vessels three years later.

This is not the first time items at the Museum have re-entered service. The *Skylab* portable shower and portable foot restraint system and part of the ATS-6 satellite have also been taken out of retirement for testing or active duty.

Allan Needell, a curator in the Musem's Space Science and Exploration department, is satisfied with the Oscar 17 trade. "We now have a more valuable item in the collection," he says. The Air Force should be pleased as well: using the Oscar 17 should save at least $2 million.

Museum Calendar

Except where noted, no tickets or reservations are required. Call Smithsonian Information at (202) 357-2700 for details.

Fall Film Series. Feature film and selected aviation short in Langley Theater, Tuesday nights, 7:30 pm. October 7: *Thirteen Hours by Air,* preceded by an episode of *Captain Midnight.* Richard Webb, Olan Soulé, and Sid Melton from *Captain Midnight* will introduce. October 14: *The Hunters.* October 21: *Twelve O'Clock High.* October 28: *God Is My Co-Pilot.* November 4: *A Fighting Lady Speaks* and *Men of the Fighting Lady.* November 11: *Dawn Patrol.* November 18: *Memphis Belle, Combat America,* and *14th Air Force Story* and/or *The Fight for the Sky.* November 25: *The Bridges at Toko-Ri.*

October 4 Monthly Sky Lecture, 9:30 am. "From Here to There: Early Celestial Navigation," Albert Einstein Planetarium. James H. Sharp, planetarium chief.

October 16 General Electric Aviation Lecture, 7:30-9 pm. Langley Theater. Chuck Yeager, U.S. Air Force Brigadier General, Retired.

October 30 General Electric Aviation Lecture, 7:30-9 pm. Langley Theater. Pierre Clostermann, French World War II ace.

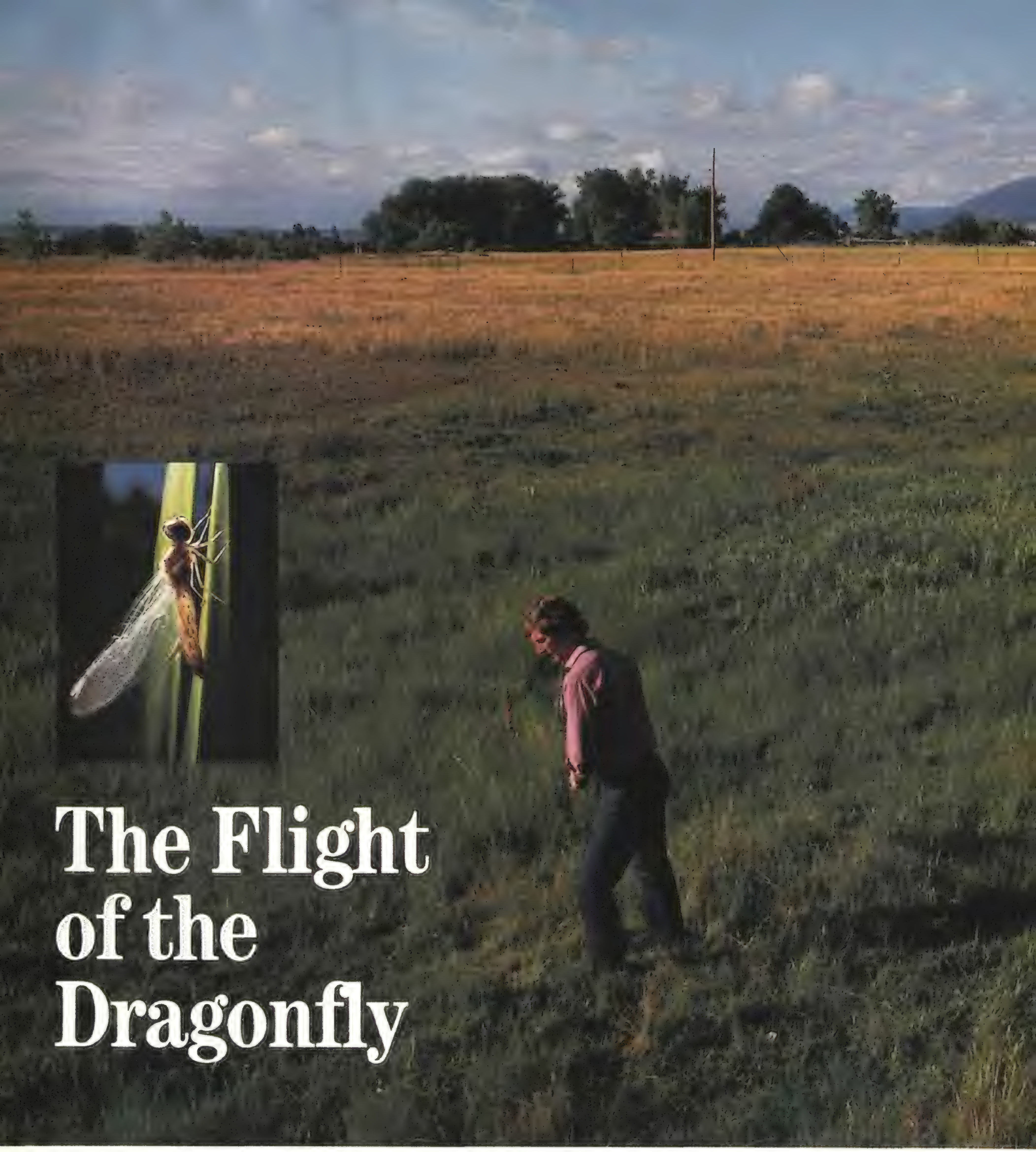
November 1 Monthly Sky Lecture, 9:30 am. "Computers in Space," Albert Einstein Planetarium. Paul Ceruzzi, from the Museum's Space Science and Exploration department.

November 10 Caproni CA 9 exhibit opens in the "Early Flight" gallery.

November 20 "State of the Universe" planetarium show debuts. Continual showings daily, Albert Einstein Planetarium. Tickets required.

Come visit your Museum on a "Washington Anytime" weekend—two nights (double occupancy) for $99. Includes accommodations, some meals, Museum tour, Smithsonian Castle tour, IMAX film. For details, call or write to the Associates Travel Program, Capital Gallery 455, Smithsonian Institution, Washington, D.C. 20560. (202) 287-3362.

—Tom Huntington

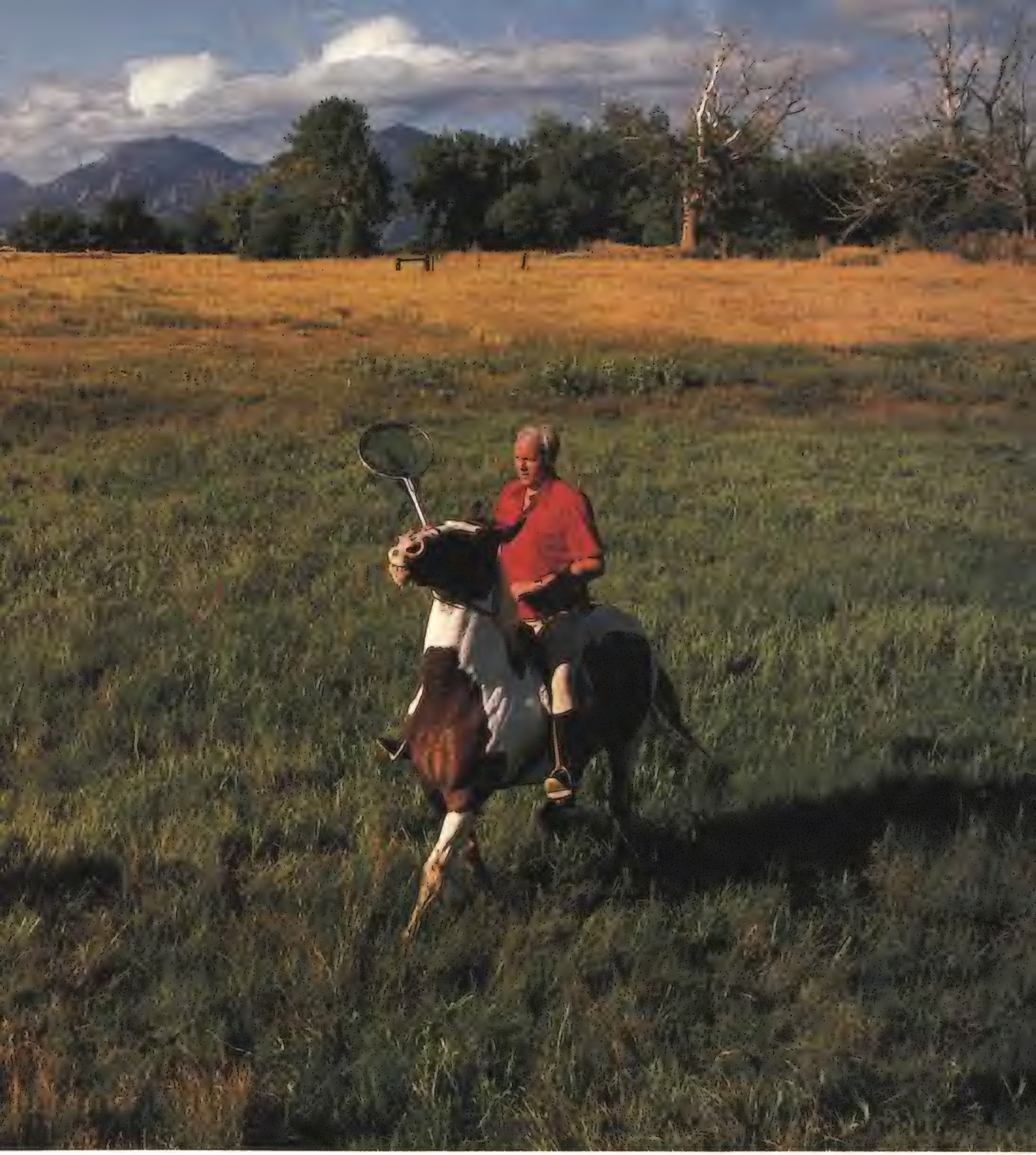


The Flight of the Dragonfly

Aeronautical engineers take the bugs *out* of airplanes.
Marvin Luttges wants to put them in.

By Richard Wolkomir

From its perch on a pondside cattail, a green dragonfly rises like an elevator straight up into the sunlight. It hovers, then shoots bullet-like over the water. It makes a right-angled turn. It flies backward. Whizzing back to the cattail, it sinks straight down, alighting



like a feather.

The dragonfly poses with its four translucent wings outstretched in the Rocky Mountain sunshine, as if awaiting applause for its trick flying. Instead, a University of Colorado aerospace student bags it with a butterfly net.

Half an hour later, the dragonfly is flying again, but now in a vast underground laboratory beneath the Boulder campus' Engineering Center. The insect, tethered inside a wind tunnel half the length of a football field, flaps heroically in an artificial gale. An aeronauti-

Marvin Luttges (right) and Mark Kliss round up dragonflies outside Boulder for aerodynamic studies.

Photographs by Paul Chesley

Sitting behind an X-29 fighter wind-tunnel model (foreground), student John McGlinchy glues a dragonfly to a toothpick (right).

A modern dragonfly finds a moment's rest atop the fossilized portrait of a Paleozoic ancestor (below).

Robert Noonan

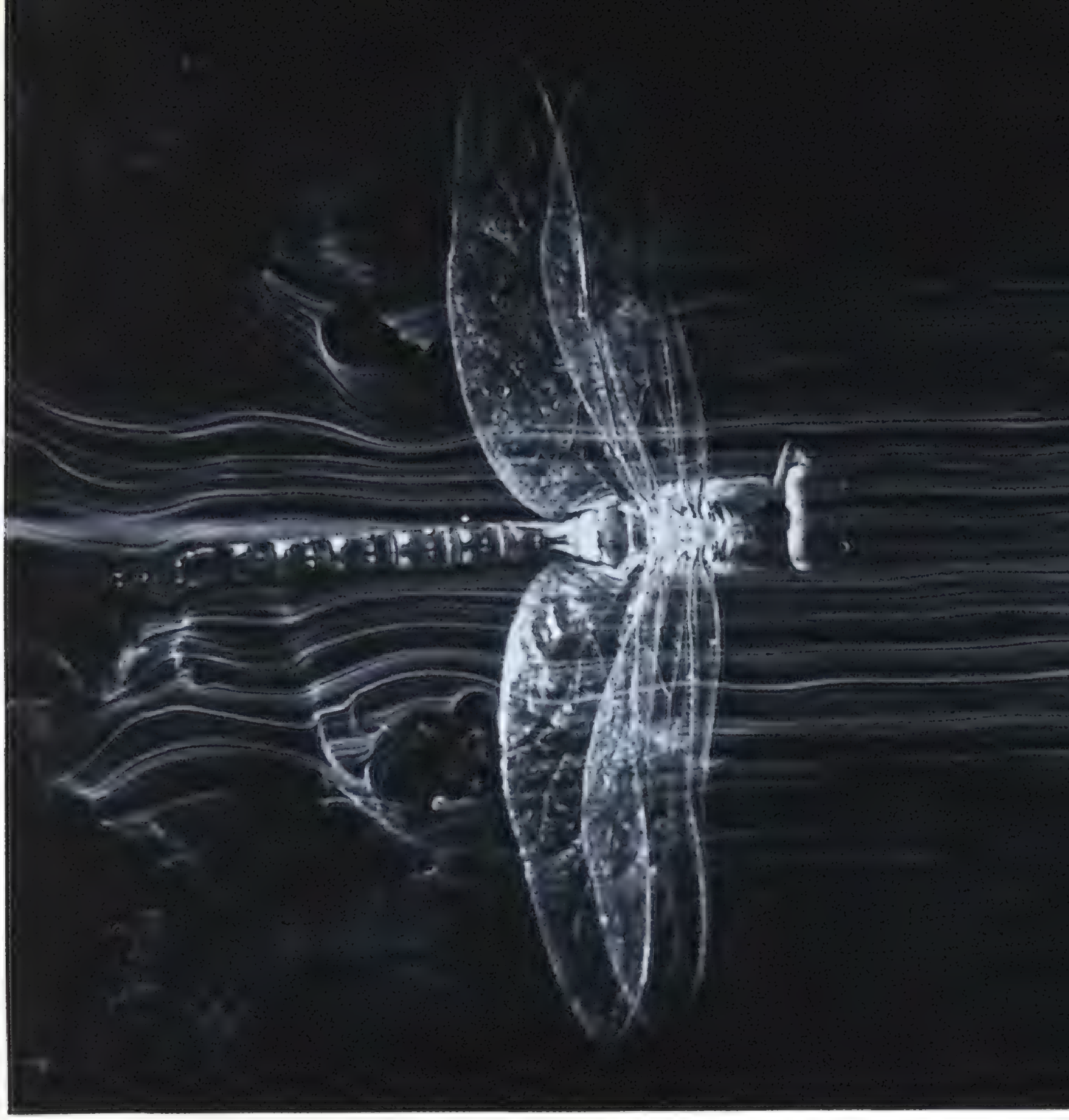
cal engineer wearing sneakers, jeans, and a T-shirt fingers a computer keyboard as he peers at the insect through a plastic window in the side of the wind tunnel. Smoke begins streaming past the dragonfly, eddying and whirlpooling over its beating wings, roiling behind. A strobe flashes like lightning, a camera whirs, and, helped by the tiny superflier in the wind tunnel, humanity moves another step toward an altogether new technology of flight.

The godfather of dragonfly studies, University of Colorado aerospace professor Marvin Luttges (pronounced like "clutches"), says the insects show that the way today's airplanes fly is not necessarily the best way. One day, he declares, we may thank dragonflies for airplanes that are far safer, quieter, more economical, require only tiny runways, and fly like archangels.

Studies of dragonfly flight began in 1980 when Luttges, a John Wayne-sized former football player, began pondering one of the hottest new subjects in aerodynamics: unsteady flow. Today's airplanes rely on a steady flow of air moving smoothly over and under their wings to create buoying lift. However, air sometimes flows unsteadily in a swirling, eddying vortex. And such unsteady flows are packed with energy.

"Nature is full of unsteady flows—gusts of wind, microbursts, tornadoes, hurricanes," Luttges says. Until now, unsteady flows have been mainly aero-

A Smithsonian diorama recreates an era when bird-sized dragonflies darted through prehistoric skies (right).



Attached to a toothpick, a dragonfly fights valiantly through streams of "Roscoe Fog Juice" in a University of Colorado wind tunnel. The fog and a flashing strobe light allow cameras to capture the vortexes wafting over the insect's translucent wings, which help give the insect remarkable lift.

Sensor cells in the dragonfly's wings let the insect detect and utilize the vortexes for lift, as the front wings feed them to the back. Researchers visualize a day when airplanes will flex and bend their wings like dragonflies.

dynamic pests. "We found, for instance, that unsteady flows play havoc with helicopter blades," he says. Each blade produces vortexes in the air that buffet the next blade, and after a few hundred hours of service the metal begins to fatigue. But Luttges wondered whether there might not be a brighter side: "We thought, maybe we can do something to extract some of the considerable energy from unsteady flows."

Among aerospace researchers, Luttges is an oddity: he's a neurobiologist. And so, his natural instinct was to use a so-called "biological model" to study unsteady flow. "There's a whole bunch of frustrations in trying to answer questions about how insects and birds fly," he says, "but you don't have to be really bright to guess that they generate lots of unsteady flow."

Luttges started studying bird flight and constructed a simplified aluminum model of a bird's wing, even simulating feathers with fibers. In wind tunnel tests, his team discovered the wing to be dramatically resistant to stalls—loss of lift—compared with conventional airplane wings. "But we were really doing the wrong thing," he reflects. "A bird has a highly developed nervous system. It can deploy feathers, change the shape and extension of its wings . . . a darting hummingbird or a swooping swallow is just too complex to study." There had to be an easier way.

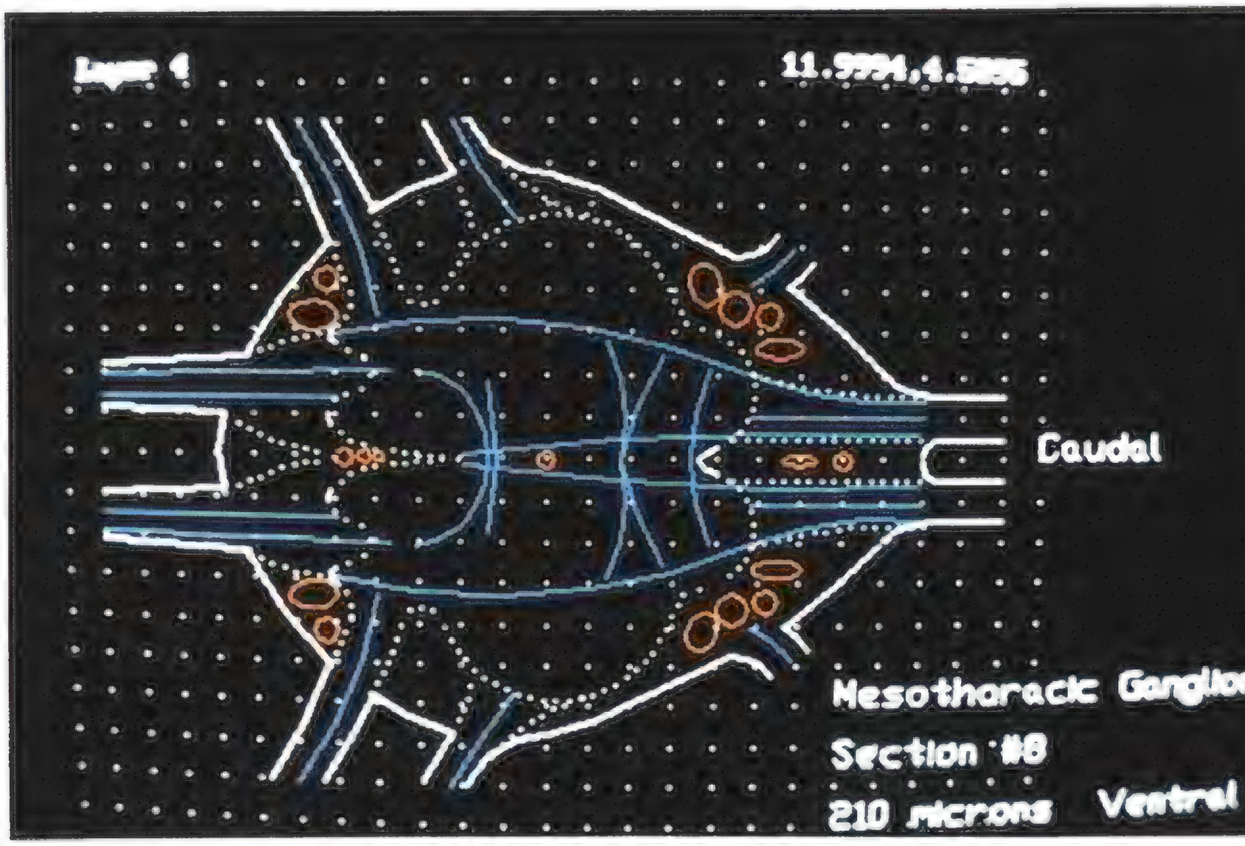
While horseback riding one day, Luttges began pondering insects, much simpler flying machines than birds. He remembered his childhood in Dixon, California, near the Sacramento River delta, where he would spend hours admiring dragonflies as they darted after mosquitoes. Now he began to watch the dragonflies hovering and swooping over the plains near his home on the outskirts of Boulder.

"I decided to study the flight of dragonflies . . . and then I reasoned out *why*," Luttges says. For one thing, like DC-10s and Piper Comanches, dragonflies cannot fold their wings, suggesting simple muscles and neurological systems. "Also, their wings have no deployable devices," says Luttges. And dragonflies have a long service record.

Their design has changed little since they first began darting over the Earth's wetlands some 260 million years ago,

Student Mark Kliss attempts to unravel the inner works of a specimen under his microscope (above).

Study of dragonfly ganglia—tiny groupings of nerve cells—may lead to "smart" airplane wings (right).



millenia before the first dinosaurs crawled out of the Permian muck. Those early Paleozoic dragonflies were as big as sea gulls, ace aviators of the giant fern forests, while today's models have shrunk to the size of pencil stubs. But they still have four wings, sometimes gorgeously smoked or tinted with red, blue, black, or green. And they are still demon fliers. "Any design that has worked so well for so long is worth studying," Luttges says.

He began making expeditions into his yard armed with a high-speed camera to photograph the insects in action. "I'd been watching dragonflies for the better part of my life, but I found that I'd never really been seeing them," he says. "For instance, I thought their wings made only a slight flutter, but photos showed their flying motion is a deep flap."

The next step was learning how to capture the dragonflies. Luttges discovered that a startled dragonfly always shoots forward, up and away at a 45-degree angle. He found he needed only to hold a butterfly net in front of the insect, startle it, and it would fly into the net. "The truth is, they're kind of stupid, which makes it easy," he says.

The dragonfly study has now grown to include two other professors and a platoon of 18 graduate students. Because it is a prerogative of professors to occupy their minds with grander thoughts, it falls to the students to net the required two or three dragonflies per day. (That's during the summer, dragonfly season. During winter, the researchers focus on such tasks as watching wind-tunnel films.) "The insects make regular rounds, patrolling their territory, so we wait for them with the net and then put them in a coffee can, with a reed for a perch," says Mark Kliss, a doctoral candidate in aerospace engineering at the university. "A fisherman watched me netting dragonflies one morning, and then he asked, 'Son, didn't you ever get interested in bicycles, women, or cars?' "

In 1982, when Luttges began the dragonfly flight studies in the laboratory, all the techniques had to be invented. For instance, to determine how much lift a dragonfly generates in various stages of its flight, he learned to cool a freshly captured specimen into temporary quiescence. Luttges then would attach its shell-like carapace to a toothpick with a dot of glue. He attached the opposite end of the toothpick to a force balance, a complicated device that looks vaguely like a dentist's chair for elves and measures minute pressures deflecting its sensitive arm.

"We found that a dragonfly generates lift amounting to seven times its body weight, so we thought we were doing something wrong," says Luttges. After all, he says, airplanes with the highest performance generate only 1.3 times their weight in lift. To check their results, the researchers tied small brass weights to dragonflies. Shocked, they watched the insects hoist the loads with aplomb. Dragonflies, it turned out, are indeed prodigious generators of lift. The next task was to find out why.

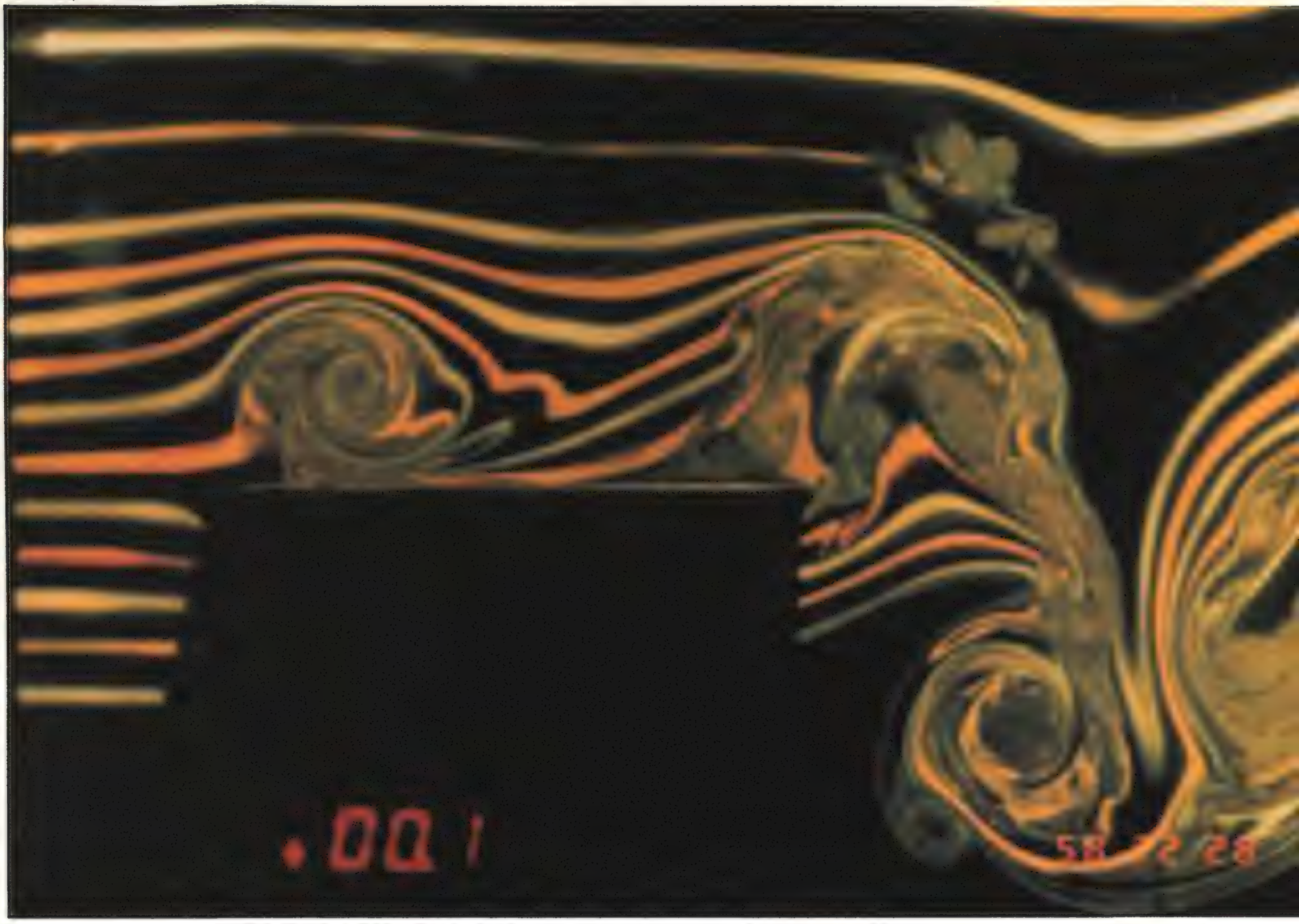
Luttges put the dragonflies, connected to force balances, into wind tunnels. By sending streams of smoke past a flapping insect, he could see—and photograph—the airflow over its wings at various stages of flight. It was clear that the cellophane-like wings create swirls of "uneven flow," vortexes that glide across the wings. It is these vortexes that give the dragonflies their exceptional powers of flight. Discovering exactly how the process works, however, demanded many hours of wind tunnel tests. That presented a problem, at first, because the smoke usually used in the tunnels was toxic.

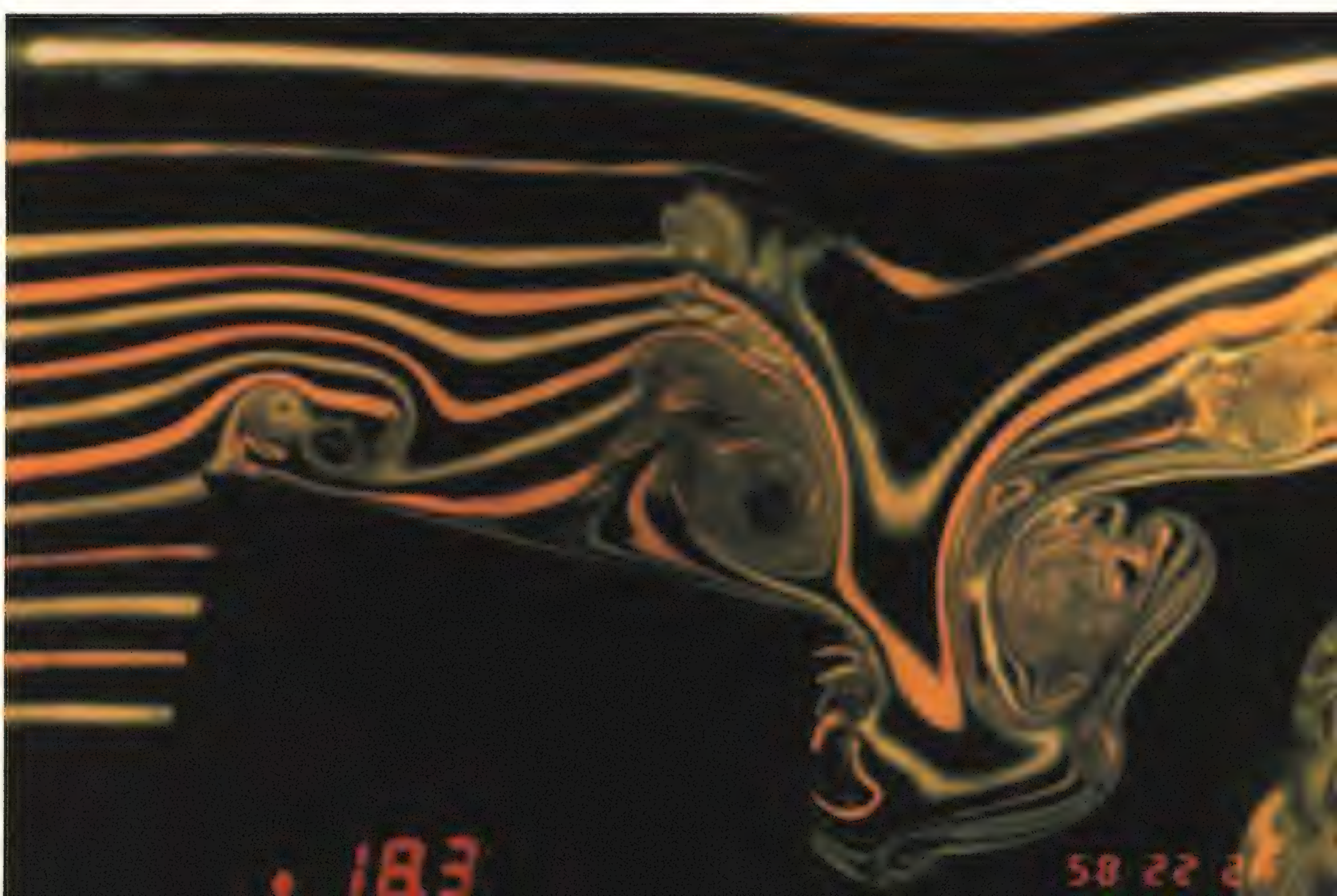
"One night I was at a campus theater watching *Macbeth* when I noticed that smoke was billowing all over the stage, and I began to wonder how they did it without asphyxiating the actors," Luttges says. He discovered that theaters use an insect fogger containing a compound called "Roscoe Fog Juice." Now, the university's wind tunnels use a new nontoxic smoke, compliments of the Bard and the unknown Roscoe.

Many flights through the Fog Juice later, the tests are continuing. "We're still studying the vortexes' effects on dragonfly wings," Luttges says. "We're trying to gather such information as all the forces at work at each point in every wing-beat cycle." The job should be done soon, representing a considerable technical achievement. "A collection of data like this has never existed before on the flying characteristics of any organism," he says.

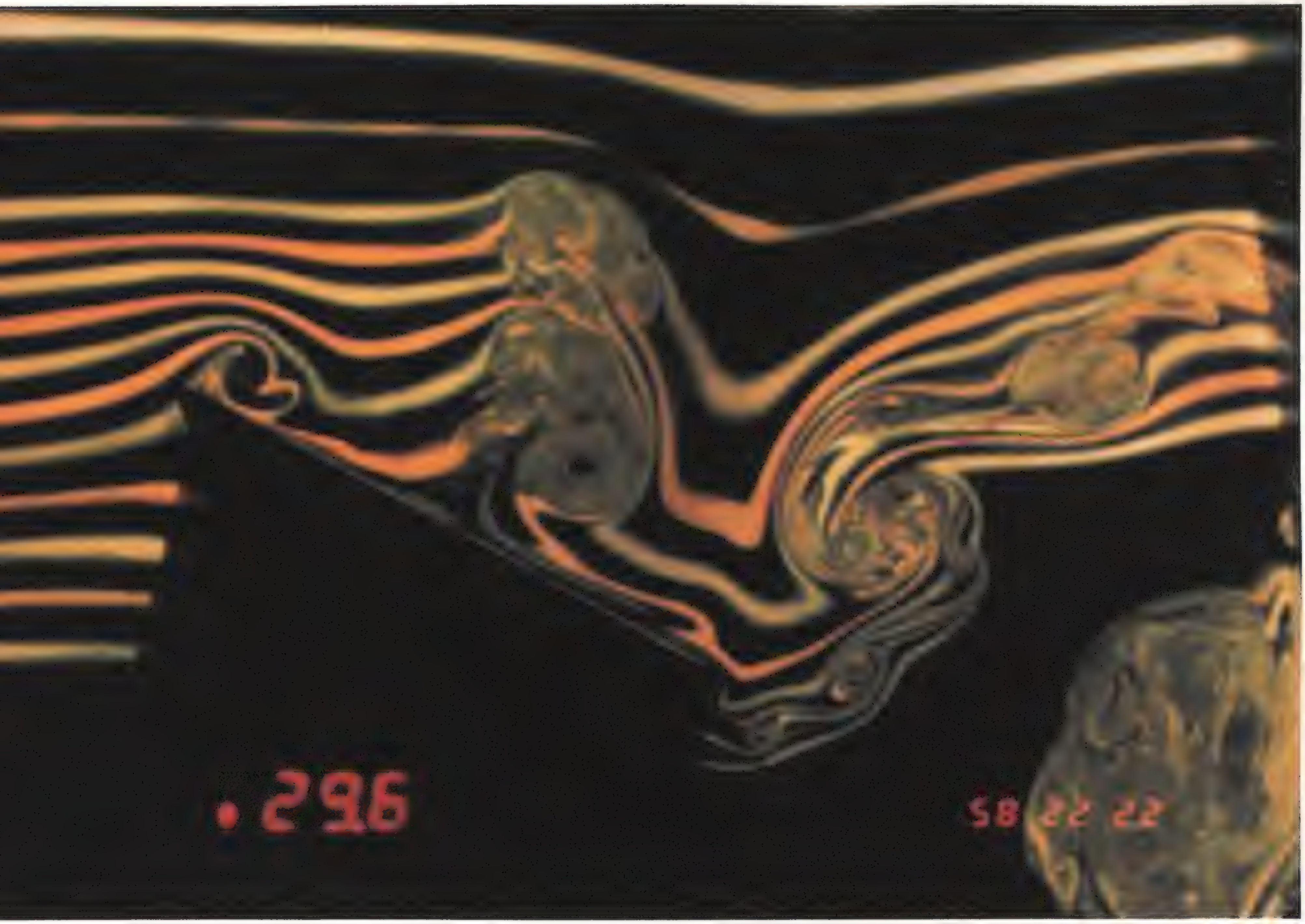
A printout of ganglia activity provides a resting place for one of the world's greatest fliers.

Gad-el-Hak/Flow Research





At the Flow Research Company in Kent, Washington, dragonflies and wind tunnels are replaced by rectangular wing models and water-filled flumes 60 feet long. Fluorescent dyes, excited by sheets of laser light, make the vortexes roiling over the wing models visible for the whirring cameras.



Interesting as the data may be biologically, however, the aim of the research is to build better airplanes. In fact, since 1983 the Air Force has been funding the dragonfly research. Thus, the scientists must learn not only how the insects generate uneven flows over their wings, but also how their muscles and nerves control the vortexes and put them to work. "We're trying to learn what information the dragonfly collects in deciding how to change the pitch of its wings and the frequency, stroke, and phasing of its wing beats," says Christopher Somps, an aerospace engineer "with a biology tilt."

Somps' neurobiology team works in a lab jumbled with computer screens, homemade electronics, oscilloscopes, refrigerators, and enough gadgetry to fill a TV repair shop. Using incredibly tiny needle-like probes, team members monitor the firing of specific nerve cells, a kind of eavesdropping that teaches them how a dragonfly operates its superb flying equipment. "One thing we've found is that the up-and-down motion of the wings is really not critical for flight—it's subtler motions that give the dragonfly its control," Somps says. "Also, dragonflies have sensor cells that stick up like hairs along the large wing veins, which sense the airflow, and other nerve cells that gauge the bending of their wings."

Luttges, his moccasins resting on the chair in front of him, watches a wind tunnel film of one of his winged protégés valiantly flapping its way through the Fog Juice. "Look!" he says, as a vortex forms like a black blister atop a front wing. "The front wings feed vortexes to the back wings." On the screen, the vortexes bounce to the rear wing, slowly sliding from the leading edge to the trailing edge, and then disappear in the roiling wake.

Dragonflies, the studies show, tap the energy in such vortexes for lift. In a vortex, the swirling of the air drops the pressure at the vortex's center, much as the air pressure is lower inside a hurricane. Thus, a vortex moving across the top of a wing lowers the pressure of the air pressing down on the wing, increasing its lift.

Tomorrow's airplanes, in Luttges' vi-

A model built by Luttges and student Dan Sarharon demonstrates a dragonfly's lift characteristics.

Even dragonfly hunters break for levity, à la this doctored Gary Larson cartoon on a laboratory bulletin board.

sion, will be masters of vortexes. The secret will be "smart" wings, studded with sensors to detect vortexes forming in the airstream (electronic analogs to the dragonfly's wing neurons). The wings, controlled by computer, will change their shape to match air conditions, milking the vortexes passing over them for lift. "You might even have lasers that point out from the wings' leading edges, 'looking' at the incoming flow of air for vortexes," Luttges says. "The wings will be continually flexing and reconfiguring, and when the pilot calls for a climb or some other maneuver, the computer decides the best wing shape."

Indeed, team members are already experimenting with technologies that would allow airplanes to emulate dragonflies. For instance, they have found that the rate at which a wing pitches up and down provides a degree of control over the formation and character of the vortexes. "Previously, these unsteady flows had been thought to be unpredictable, uncontrollable," says Luttges. "The problem with relating control to pitch rate, though, is that an airplane might rip off a wing, so we've been fooling around with vortex generators."

He demonstrates one such device: a thin metal strip on the leading edge of a model wing, flush with the wing's skin, that pops up like the feathers on a bird's wing. "This creates nice vortexes, and it gives you lots of lift enhancement," he explains. A later version, he says, uses a pulse of air from nozzles in the wing rather than a metal strip on the leading edge to create vortexes.

"More recently, we've found that different wing shapes—delta wings, say, or wings that are swept back or forward—have an effect on vortexes, for better or worse," Luttges says. "For example, vortexes generated at the wing tips can wash inboard and hurt the lifting characteristics of the inner wing. But if you put something like feathers on the wing tips, it destroys the cohesiveness of those destructive vortexes." Northwest Orient will soon install special tips on the wings of some of its airplanes to cancel vortexes. "Now we're looking into the possibility of different wing tips to use *all* the energy from uneven flows," he says.

The Colorado scientists are not alone in their attention to uneven flows. Researchers at Flow Research Company in Kent, Washington, Illinois Institute of Technology, and nearly 60 other organizations around the country are now looking into the aerodynamic possibilities of vortexes, much of the research funded by the Air Force.

"Behind all this is the Air Force's interest in the next generation of fighters, which will be super-maneuverable," says Mohamed Gad-el-Hak, an engineer at Flow Research. "The data we're gathering from basic research will eventually help designers create new kinds of airplanes that can carry out extreme maneuvers, like super-tight turns, without losing lift."

According to Gad-el-Hak, aerospace corporations like Boeing already are incorporating the unsteady flow research into designs for new ultra-high-tech fighters, perhaps flown by computers responding to voice commands from the pilot. He expects that the first of this new breed of aircraft will be in the skies, looping and zooming, in a decade or so.

Luttges holds up a model of a Grumman experimental airplane, the sleek X-29, as an early example of where airplane design could be heading. Something like the four-winged dragonfly, the airplane has two stubby winglets—"canards"—in front, and two main wings that sweep forward. The X-29 is so hard to fly that pilots need help from three computers. So far, the airplane has not used all its capabilities. "Those canards can wiggle and generate vortexes, but they're not using that configuration yet," Luttges says. "We have one researcher finishing up his doctorate who flew F-4s for 12 years and who's now specifically interested in finding ways for the X-29 to exploit unsteady flows."

Meanwhile, Luttges is already planning to move beyond dragonflies, and has his eye on uncharted entomological territory. "Our next step will be to look at a more complex insect, the hawk moth," he says. "It's a marvelous flier—you can mistake hawk moths for hummingbirds. And it has two continuous wings—much more complex than the dragonfly's four wings—that distort in all directions as the moth flies."

Marvin Luttges leans back, obviously pleased with his thoughts about dragonflies and moths. Overlooking his desk is a photograph of a palomino, its lips curled back in a mocking horse laugh. But Luttges sees nothing amusing about applying lessons from the entomological world to the aeronautical realm, where computerized, multi-million-dollar, Mach 2 machines are everyday fare.

And so, the last laugh may not be the palomino's. Airplanes, held aloft by the energy in vortexes, may one day flit through the sky, their smart wings constantly flexing and changing shape as the airplanes take off almost vertically, turn on a dime, speed faster than bullets, slow to a virtual hover, and land on a postage stamp, feather-light.

We have seen the Propeller Age give way to the Jet Age. Now we may be entering a new era in aviation—the Age of the Hawk Moth.

Solid-Fuel Rockets

The simple skyrocket has grown up into a giant booster. But the future for solid-fuel rockets is no longer a simple matter.

By Kurt Stehling

Illustrations by Dale Glasgow

Shortly after the space shuttle *Challenger* exploded last January 28, speculation focused on two possible causes: failure of the powerful pumps that deliver liquid fuel to the main engines, or a malfunction in one of two solid-fuel "strap-on" boosters that straddle the bulbous expendable fuel tank. The pumps operate near their design limits and are always watched carefully, monitored by sensors whose data is telemetered to the ground. In this instance, the data showed faultless performance, and the pumps were absolved of blame. Further investigation revealed that a flame from a joint between segments of the solid-fuel booster on the right side of the shuttle caused the explosion.

Not long afterward, on April 18, an Air Force Titan rocket blew up, destroying a costly intelligence satellite and damaging its launch pad at Vandenberg Air Force Base. Again, the solid-fuel booster was blamed, and in the aftermath, the design of segmented boosters has come under intense scrutiny.

The boosters used on both the shuttle and the Titan are the latest and largest descendants of a long line of solid-fuel rockets that have been around since the time when the ancient Chinese are thought to have invented gunpowder and used it to make what we know today as the "skyrocket." In that primitive form, the rocket probably traveled through Arabia to Europe, where it was first used in warfare during the thirteenth century, and later, for ceremonial fireworks displays.

These first simple rockets were tubes of wood or metal with pointed noses, clay nozzles at the business end, and long sticks at the tail to provide stability. The tube was packed with gunpowder into which a fuse was embedded. The powdery fuel was mixed with tar, resin, or hard grease to keep it from dribbling out the nozzle. This solid-fuel mixture has traditionally been called "grain." When it was ignited, the hot combustion gases escaped through the nozzle at the rear, and the rocket took off.

Gunpowder burns very rapidly—it's more like a prolonged explosion than combustion—and the erratic flow from a skyrocket's exhaust jet produces an imprecise flight path. In the eighteenth and nineteenth centuries, some seemingly minor but actually important improvements transformed the skyrocket into a more accurate, stable, and compact missile. A bell-shaped expansion nozzle was added to the exit orifice, or throat. This single improvement increased the propulsion efficiency of the rocket by allowing the expanding gas in the nozzle to "focus" its force and produce more thrust.

Around 1800, an English colonel named William Congreve developed a stabler, more accurate rocket with a slightly tapered metal case and the guide stick mounted on a bracket in the center of the exhaust nozzle. In the mid-1880s another Briton, William Hale, removed the stick and placed metal vanes set at an angle within the rocket's exhaust. These vanes made the rocket spin, thereby stabilizing it like a gyroscope.

The "rockets' red glare" from the British bombardment of Fort McHenry, in Maryland, during the War of 1812 found its way into Francis Scott Key's "Star-Spangled Banner." But rockets were being replaced by modern, more accurate cannon. By the end of the century, the rocket was confined to an occasional attempt to shoot life-saving lines to shipwrecks and to send signals. Rockets were little used in World War I, which was dominated by artillery and the machine gun. The French produced a successful rocket fired by fighter aircraft at German observation balloons, and rocket flares were used as signals during night attacks.

After the war, the idea of using rockets for travel into space gained legitimacy, emerging from the fantasy of science fiction writers to become a matter of scientific and engineering activity and conjecture. Robert Goddard of the United States, Konstantin Tsiolkovsky of the Soviet Union, and Hermann Oberth of Germany wrote and lectured to a public that had an insatiable curiosity about future flight high in the atmosphere—and on into space.

Goddard did more than talk; he began to experiment, initially with small liquid-fuel rockets in the 1920s and 1930s, but

A cluster of solid-fuel boosters will add its ring of fire to give a Delta rocket an extra kick.


9
4

Michael Freeman

Modern Thais celebrate with an ancient form of fireworks—the gunpowder-fueled skyrocket.

with the clear intention of developing larger vehicles. Goddard thought—and Tsiolkovsky and Oberth agreed—that only liquid propellants could provide the necessary performance to attain high altitudes. These early pioneers considered solid fuels unsuitable for space flight: solids offered relatively low energy, could not be stopped and restarted, were impossible to control or "throttle," and the difficulties and dangers of casting grain for large motors were deemed insurmountable.

Experimenters continued using solid-fuel rockets, often homemade ones, in such dramatic but short-lived projects as rocket mail-transfer between two villages in Austria separated by a low mountain. Someone even suggested a mail-carrying rocket to bridge the English Channel. But some of these enthusiasts began to cool to the use of solid fuels when a well-known German experimenter, Reinhold Tiling, and a couple of his helpers died in the explosion of their grain-casting shed.

The differences between solid and liquid fuels led to significant differences in the design of the vehicles that used them. Today's liquid-fuel rocket motor is virtually unchanged from its earliest form. One liquid, a hydrocarbon or liquid hydrogen, provides the source of chemical energy. A second liquid serves as a source of oxygen for combustion. Both propellants are stored in separate tanks and pumped under pressure into the combustion chamber, where they are ignited. Chamber pressures as high as 1,000 to 2,000 pounds per square inch build up during combustion, and the escaping gases depart through a nozzle at the rear. The motors require lots of plumbing: networks of tubing, massive pumps and complex valves to maintain the correct rate of flow and ratio of fuel to oxidizer. Even the combustion chamber can be complex, made of a bundle of tubes welded together to make a chamber and nozzle. On its way to the combustion chamber, the fuel passes through the tubes and absorbs heat. Their complexity makes these motors difficult and costly to fabricate. The fuel tanks also are delicate and expensive, particularly the insulated kind used for super-cold liquid hydrogen and oxygen. And liquid fuels sometimes have other problems related to limitations on the fuel pumps, unstable combustion, and the destabilizing effect of propellant sloshing about in fuel tanks.

Solid-fuel rockets are much simpler in design. Early solid grains combined a carbon fuel—most commonly, charcoal—mixed with sulfur and blended intimately with a source of oxygen such as potassium nitrate—in short, gunpowder. All the ingredients were blended together with a binder, like a pudding, and allowed to solidify. More modern grains are merely refinements of this basic practice, improved to yield higher chamber pressures and better "specific impulse"—in simple terms, the amount of thrust obtained from a pound of fuel—to produce higher exhaust-gas velocities and generate higher speed and greater range from a given amount of fuel. Because the fuel makes up a greater part of the rocket's overall weight, solid fuel produces better "miles per gallon" than does liquid fuel, with its added weight of tanks and machinery. So with solids, a given vehicle can yield higher orbits with heavier payloads.

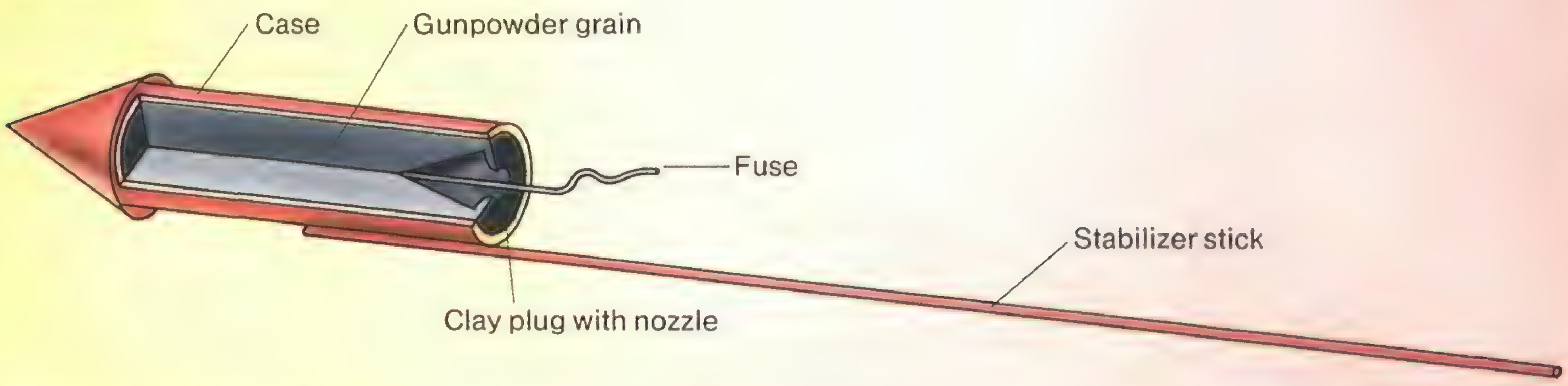
Packed into rockets, solid fuels burn from the center outward, and the grain itself acts as a flame barrier until the last of it is consumed and combustion stops at the internal insulation barrier that lines the motor case. Heavy, expensive propellant tanks are not needed. Best of all, solid-fuel motors require no pumps or valves; their only moving parts, typically, are those used to swivel their nozzles for steering.

Despite their complexity, liquid-fuel rockets became dominant among the early rocket "societies." With the help of Guggenheim Foundation money, Goddard attained some genuine successes with rocket engine tests and actual flights in New Mexico, but by the late 1930s, his activity began to taper off. The American Rocket Society (ARS) persisted long enough to merge with the Institute of Aeronautical Sciences in the 1960s. A company called Reaction Motors, formed by some ARS pioneers, started in the late 1930s and expanded during World War II on the proceeds of military contracts.

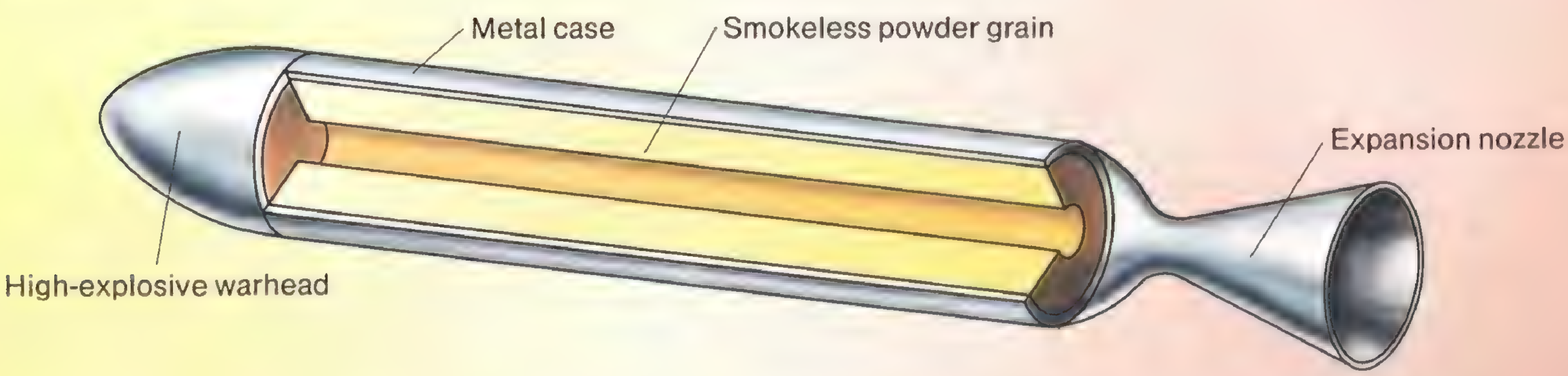
But the most active rocket societies were in Germany. Their collective expertise was soon appropriated by the Nazi party, whose military leaders could foresee applications in warfare. During the late 1930s, Germany's rocket establishment secretly began to develop large liquid-fuel rockets. The effort culminated in the V-2 missile, the first vehicle with the

Evolution of Solid Rockets

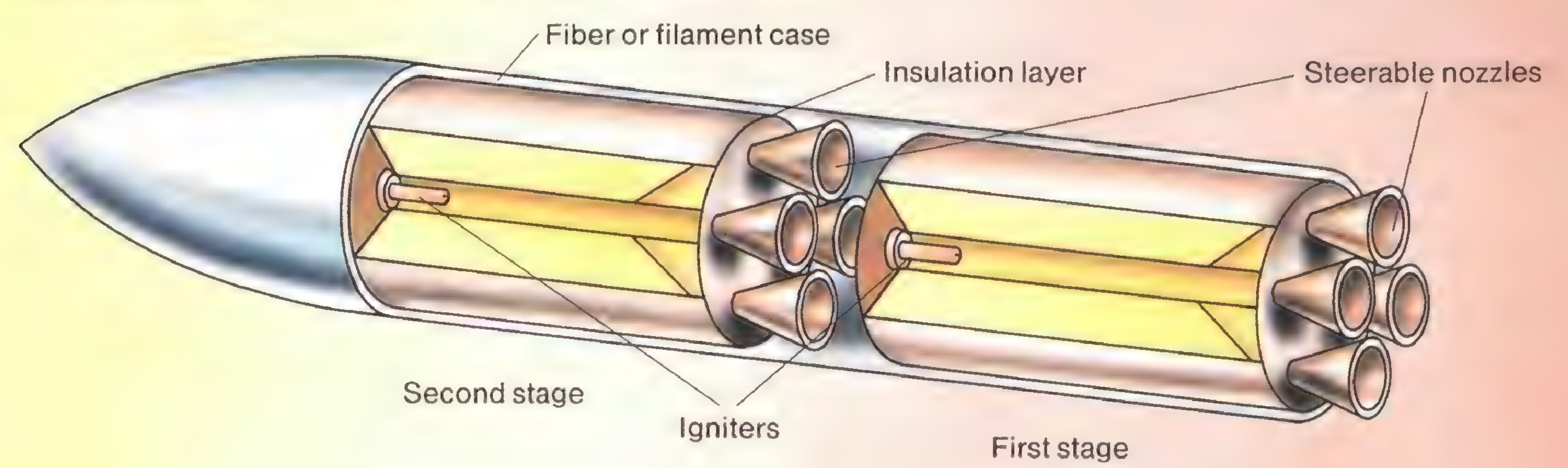
Skyrocket



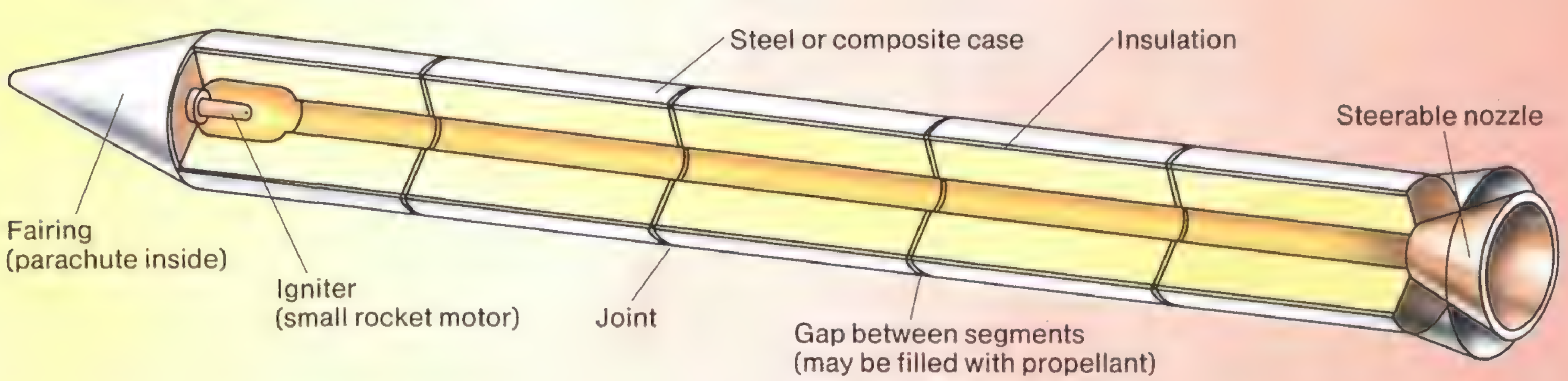
Military Rocket (World War II)



Polaris Ballistic Missile (submarine-launched)

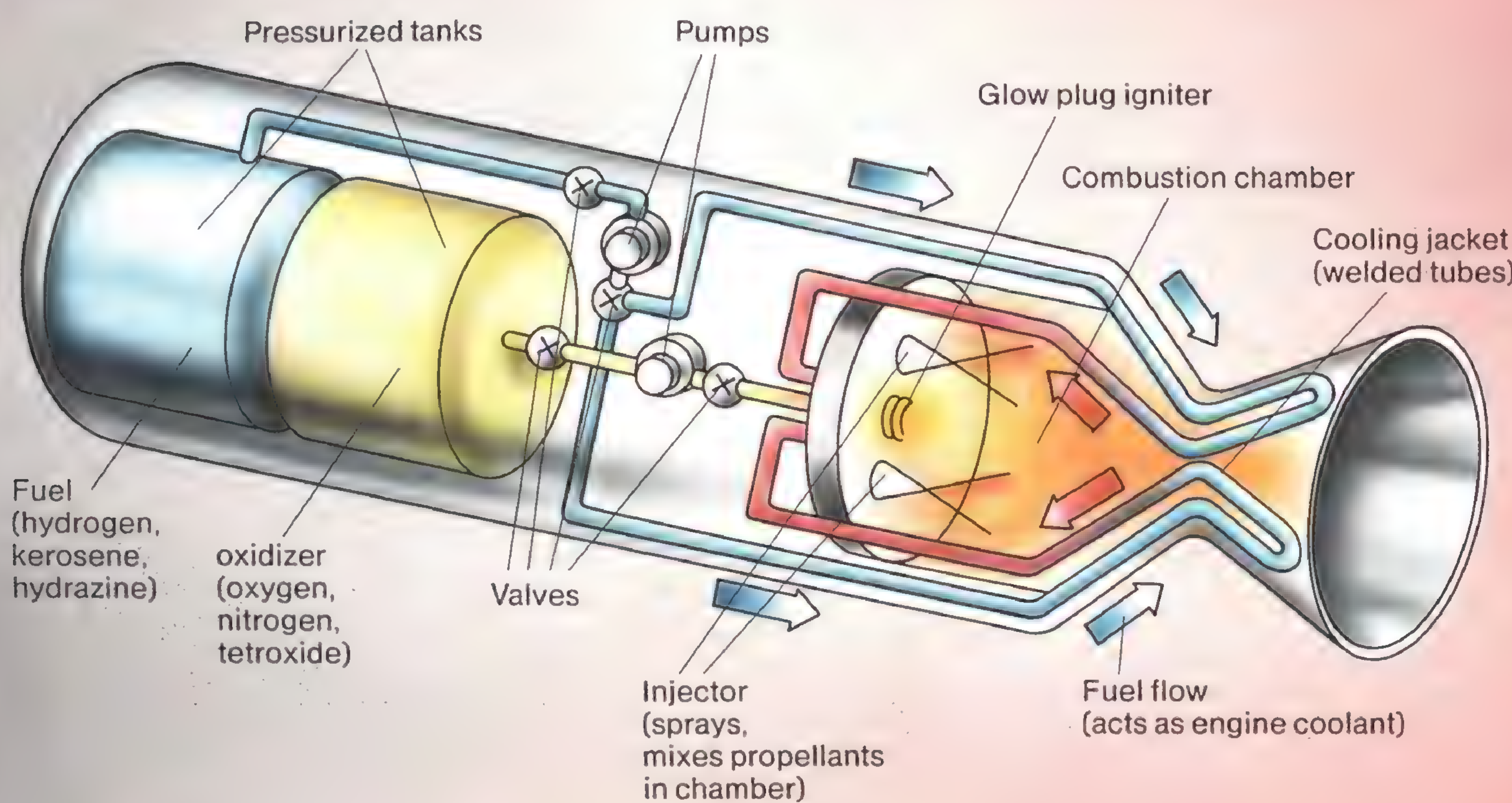


Segmented Booster (Shuttle, Titan type)



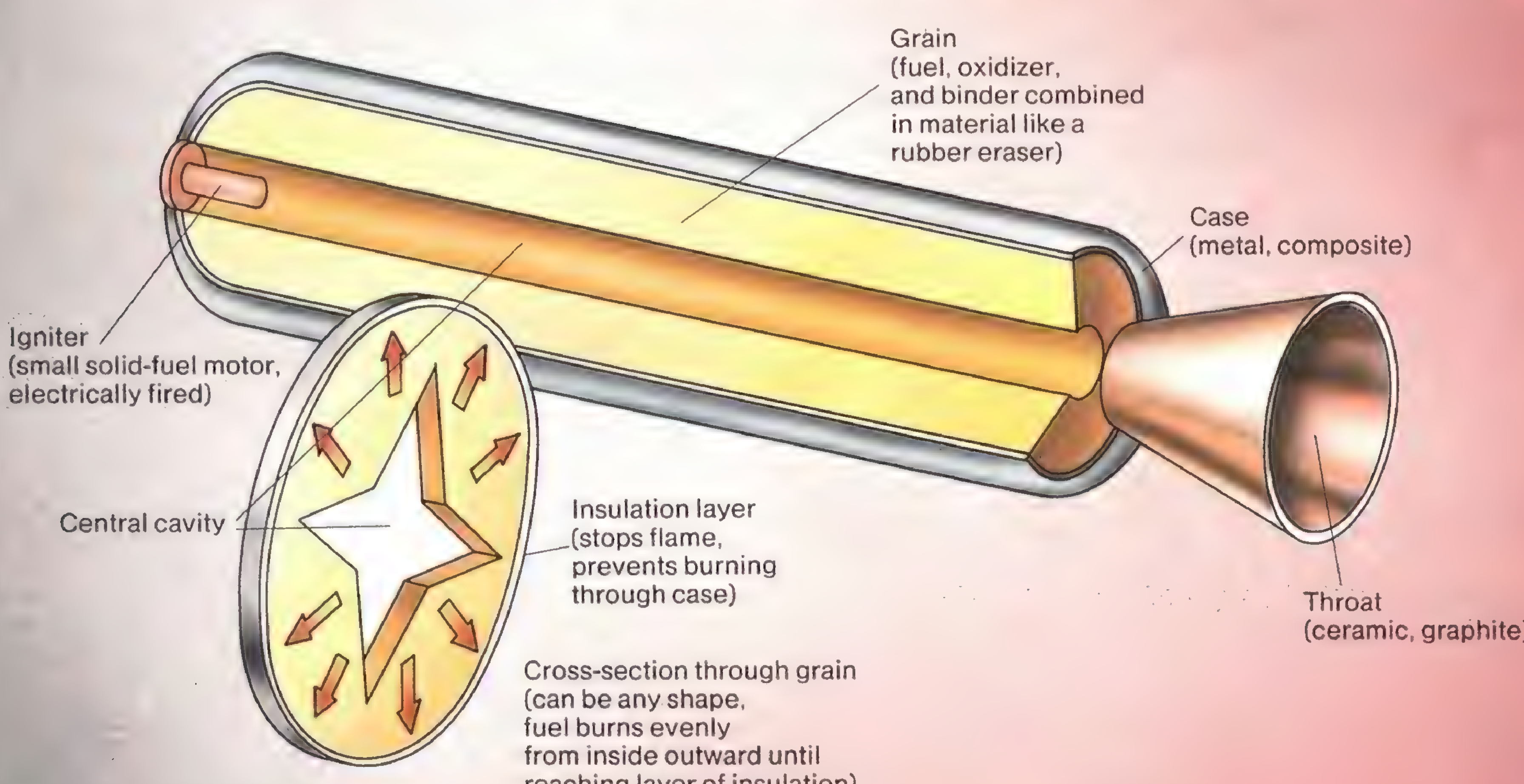
Liquid-Fuel Rocket

The motor of a liquid-fuel rocket (including the combustion chamber, pumps, valves, and plumbing) is separate from the fuel supply. Though complex, its advantage is it can be shut off and restarted on command.



Solid-Fuel Rocket

Simplicity marks the solid-fuel motor and fuel supply, which form a single unit. Ignited at the end opposite the nozzle, the rubbery grain burns outward from the central cavity until it reaches the insulated case lining.



size and range to reach an altitude of more than 100 miles—into near-space (which it did during research flights in the United States later on). Solid fuels were not forgotten entirely, as the armies of Germany and Russia fired thousands of rounds of barrage rockets that had small solid-fuel motors. The U.S. Army developed Jet-Assisted Takeoff, or JATO—actually a rocket motor in a steel "bottle" that could be strapped to a heavily loaded airplane for extra boost on takeoff.

But Wernher von Braun, chief engineer for the German V-2 and, after he moved to the United States, an architect of the giant booster vehicles for the Apollo program, never seriously considered solid fuels for the V-2—nor did he later for the Redstone ballistic missile or Saturn boosters. He argued, correctly, that the technology required to produce large solid-fuel motors was still in its infancy, and that liquids offered higher propulsion energy and versatility. At the time of the first Apollo missions in the 1960s, large solid-fuel boosters were available, efficient, and safe enough to have served as the first stage for these rocket systems, but by then, the liquid-fuel boosters had been built.

The development chiefly responsible for the eventual emergence of large solid-fuel boosters in the United States was the ballistic-missile submarine, perhaps because the U.S. Navy's submarine-launched missiles were designed from the start for solid fuels. Aside from such questions as reliability, complexity, and storage, few U.S. naval officers would even consider having a dozen 30-foot missiles containing volatile, self-reacting, corrosive, and even toxic liquid fuels in the close confines of a submarine.

Liquid fuels are, by their very nature, dangerous chemicals. They can be highly volatile, and some, such as red fuming nitric acid and nitrogen tetroxide, are quite corrosive. As one example of such a chemical appetite: in the early days of rocket tests at Bell Aircraft, when a leak sent a cloud of red fuming nitric acid billowing out over a parking lot, every convertible top it touched was dissolved into tatters. Crews who handle the chemicals used in liquid-fuel rockets have to wear gas masks and protective clothing. If anything went wrong with the storage of such substances aboard a sub, the results would be catastrophic.

Development of the two-stage, solid-fuel Polaris rocket for submarines moved solid fuel into the big time. The Polaris succeeded due to a long list of important cumulative improvements, including synthetic-rubber-based grains that are stable and insensitive to temperature extremes. "Enriched" with powdered aluminum and other additives, they produced much more power than earlier fuels. The Polaris used glass-fiber motor cases that were light but strong. Both stages had four small nozzles, each of which could move in just one direction to steer the rocket; the combination of all four provided complete steering control. The nozzles were shorter than a single large nozzle would have been, making the vehicle easier to fit into a submarine. Aerojet, the manufacturer of Polaris motors, also solved a perennial problem by inventing a way to bind the grain to the insulated motor case with polyurethane, which prevented the fuel from separating from the insulation and burning erratically.

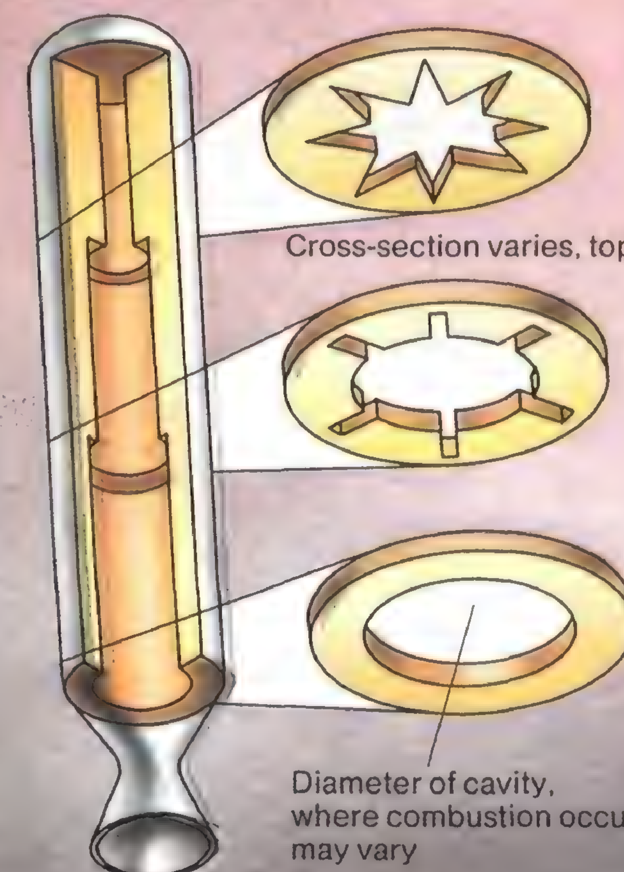
By the time the Navy got its first Polaris, the Air Force had already developed the Atlas, which ran on kerosene and super-cold liquid oxygen (LOX)—awkward to use and difficult to store. The Air Force switched to new propellants for its next generation of rockets—the Titan family—and chose easily stored liquids that eliminated the big, insulated LOX tanks. These new "hypergolic" propellants ignited spontaneously upon contact with each other and therefore needed no igniter system. But the Titans, housed in underground silos, had their inevitable problems with fuel leaks. They were complex, sensitive (a wrench dropped in one Titan silo caused a fuel spill and a terrible fire), and sometimes unreliable. The Air Force, aware of these drawbacks, began seeking a solid-fuel rocket to replace the Titan. The answer was the Minuteman, which can sit unattended in its sealed silo virtually indefinitely.

The National Aeronautics and Space Administration (NASA) also grew up on liquid-fuel rockets such as the Vanguard, Redstone, Atlas-Centaur, and Saturn. But the agency developed the remarkable Scout vehicle with solid-fuel motors as well, and the dependable Delta vehicle uses solid-fuel strap-on boosters to augment the thrust of its liquid-fuel main engines. The Scout, first launched in 1960, hasn't had an engine failure in any of its 100 flights. The Delta has performed almost flawlessly, with just one failure (which caused the mission to be aborted) out of the 895 strap-on boosters fired. The boosters are affixed to the base of its liquid-fuel first stage in bundles of up to nine.

Although they've suffered some isolated failures, the small,

Solid Fuel Internal Shape

By varying the shape of the central cavity formed when the solid fuel is cast, the amount of thrust it produces can be modified. Star shapes and notches increase the surface area of fuel available for burning and increase thrust. The volume of the cavity increases as fuel burns, tending to reduce pressure and thrust.



solid-fuel motors used for orbital transfer—to boost satellites from low orbits to higher ones—have compiled an equally resounding record of success. There's no question that liquid-fuel motors could also do a good job, but astronauts are a lot like submariners: they prefer relatively inert solid fuel in the payload bay of the shuttle instead of tanks full of self-igniting liquids. (Shuttle Centaur, a liquid-fuel transfer vehicle being developed by NASA, was recently cancelled.)

From the relatively small strap-on solid boosters like those used on the Delta grew the giants of the mid-1960s, built in response to the need to loft larger payloads. Their most visible roles have been on heavy lifters: the Titan and the space shuttle. The Titan's solid boosters, designed and built by a division of United Technologies, ushered in the era of motors built as individual segments joined together to make a single unit. The latest version is made up of six 10-foot-diameter segments: the whole motor is 90 feet long and holds 300 tons of propellant that generates 1.3 million pounds of thrust. By adding a segment, the motor's thrust increases to 1.6 million pounds, which it is expected to produce on the Titan 34D7 scheduled for launch in 1988.

Solid fuel really caught fire after the submarine-launched Polaris missile's success.

Department of the Navy

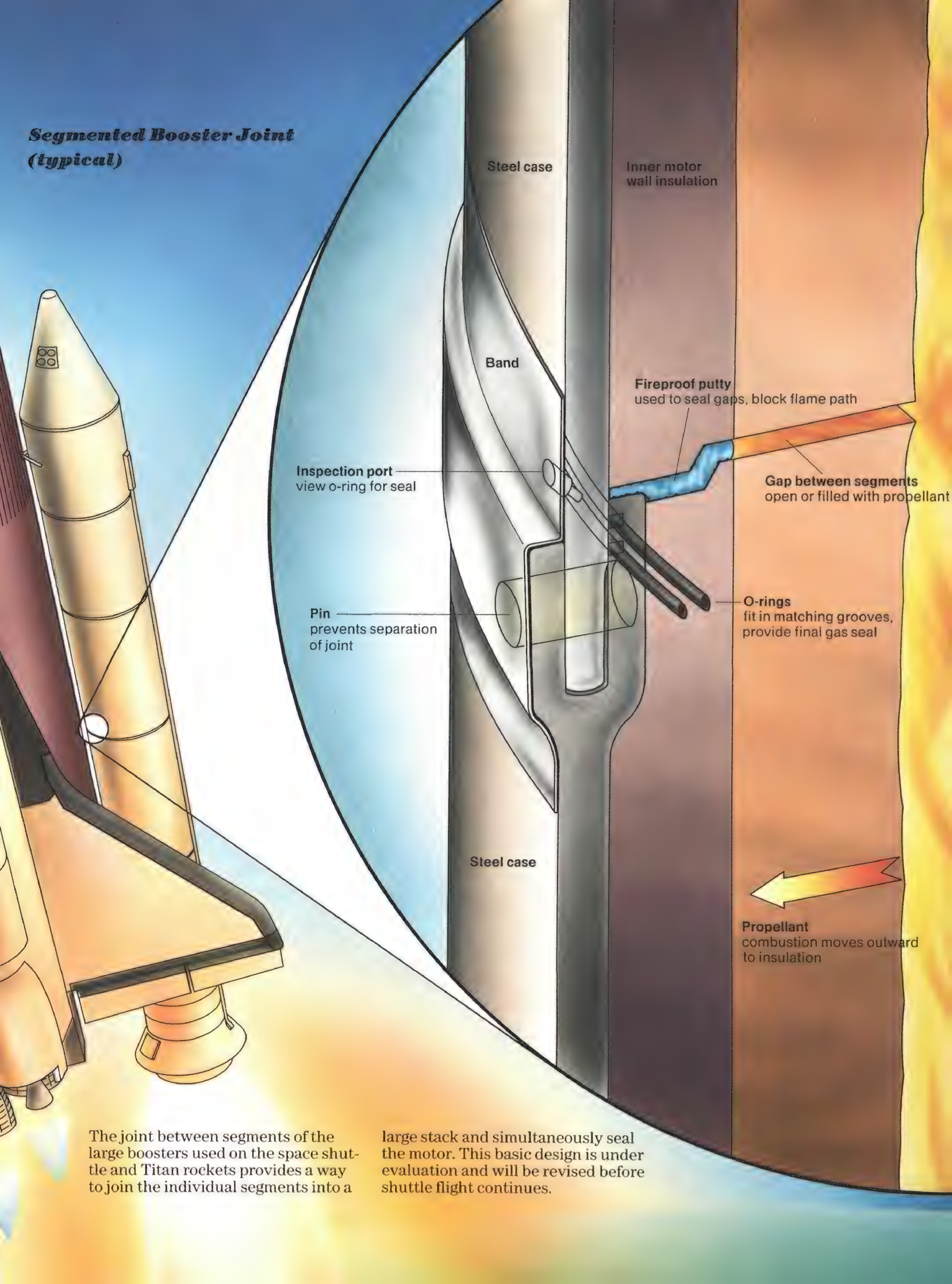
In the early 1970s, NASA awarded a contract to a Utah division of Morton Thiokol for design and production of the granddaddy of operational solid-fuel motors: the shuttle strap-on booster system. NASA chose solid fuels for its shuttle booster system because the development cost was lower and because the booster was to be recovered and refurbished, saving still more on flight costs. (Since no comparable liquid-fuel system exists, any savings is mere conjecture.)

The decision to recover some portion of the launch vehicle to reduce operating cost was pivotal. For liquid-fuel motors, recovery of the tanks was out of the question; their return to Earth intact from high altitude is impractical from both an engineering and economic perspective. The solid-fuel boosters, on the other hand, can be jettisoned intact after their shorter burn time (thus, lower altitude) and parachuted into the ocean.

Recovery ships tow the empty cases, still afloat, back to Port Canaveral, where they are hauled ashore to be cleaned and to have the exterior surface of the motor casing insulation scraped off. The cases are then disassembled into segments and transported by rail back to Utah to be completely refurbished by Morton Thiokol. Their insides are scraped clean of charred insulation, and all surfaces are scoured and abraded, pressure tested, realigned, and machined for fit where necessary. After being refilled with fresh propellant, the segments are shipped back to Kennedy Space Center, where they are stacked and reassembled into a booster motor.

However, the pros and cons of using segmented boosters are still debated among rocket engineers. The most important reason the boosters used on the space shuttle and the Titan rocket are made as segments is so that they will fit on a railroad car for shipping. If the motor is to be processed inland, as in Utah, segmented design is a necessity. Acoustic and x-ray inspections of short segments are more accurate and detailed than with large motors, so that hazardous voids, cracks, and fissures in the grain will show up more clearly. Producing propellant in smaller batches also yields higher quality fuel. And to make a more powerful motor, you have only to add a

Segmented Booster Joint (typical)



The joint between segments of the large boosters used on the space shuttle and Titan rockets provides a way to join the individual segments into a large stack and simultaneously seal the motor. This basic design is under evaluation and will be revised before shuttle flight continues.

segment or two, like building blocks.

The arguments against segmented motors are compelling. The joints in a segmented motor compromise its structural integrity. The small gap in the propellant grain between segments has caused no trouble to date but can become an undesirable flame path that would burn through a case. Segments move and warp during flight, opening the joints. Finally, while the grain itself is relatively insensitive to temperature extremes, the metal joints, rubber seals, and putty used to seal the joints can be balky at temperatures near freezing.

Some of these issues have been thoroughly aired by the investigation into the *Challenger* accident. But far less attention has been given to the premise that recovering and refurbishing solid boosters would reduce costs. The seemingly attractive concept of recovery—an old dream of many rocket engineers—may be illusory when the costs of recovery vessel and diver operations are added. Initial cleanup in port, transportation to Utah, exhaustive rework and refurbishing, a new nozzle—all these steps are expensive.

NASA

Shuttle boosters are recovered and reused, but increased risks may outweigh the purported savings.

Then there is the inevitable question of the segments' integrity after so much handling. True, Thiokol would never use a deformed or weakened steel shell, but no structure that has been through so much processing can promise the total integrity of brand-new segment casings.

NASA has now opened the door to a complete redesign of the solid-fuel booster. If NASA decides to continue using segmented cases, the joint can be made considerably more secure by welding it, which may be worth the risk inherent in the procedure because it produces a sealed case and sound structure. A threaded or screw joint would be expensive and much more difficult to assemble but is second only to a welded joint in leak resistance. Finally, the current rubber O-rings could be replaced by metal ones similar to piston rings in an automobile engine; metal rings would not burn through or blow out. Most important, if NASA abandoned the practice of recovering the boosters from the ocean, the probability for the success of any new joint design will be much enhanced.

NASA might also resurrect monolithic (one-piece) booster construction. Monolithic solids have ample precedent in what is perhaps the largest solid-fuel motor ever conceived: Aerojet General's giant monolithic booster proposed as the first stage for the Apollo moon mission launch vehicle. This monster measured 22 feet in diameter, and a half-size version measuring 80 feet long burned for 136 seconds, developing an average thrust of 3.5 million pounds. Had a full-size motor been built, it might have developed twice that thrust, or about the same as all five Saturn liquid-fuel motors that were finally used in Apollo's first stage. Aerojet built a casting, curing, and fabrication plant in Homestead, Florida. From there, it would have moved the 1,000-ton boosters by barge to Kennedy Space Center. The project established one important concept: a long, heavy motor can be built near the launch site and transported to final assembly by waterway. No existing railroad or truck line could have hauled such a monster. Some hold the opinion that a monolithic rocket of this size would be difficult to hoist into firing position. But that's a matter of engineering; mere size doesn't make it impossible to achieve.

The engineering of these huge motors advanced the technology of giant solid-fuel boosters but did little for Aerojet's bottom line: the Apollo designers, under Wernher von Braun, were wedded to liquid fuels, and the Aerojet demonstration occurred too late to make a difference. Recently, Aerojet proposed reopening its Florida facility to cast shuttle booster motors in a single piece instead of in segments, so it may still have a role to play.

The failure of two large solid-fuel boosters in rapid succession on the shuttle and the Titan does not impugn the reliability and simplicity inherent in the design of all solid-fuel rocket motors. The use of solid-fuel rockets will continue as engineering studies yield revised designs and procedures. The relative advantages of segmented as opposed to monolithic motor cases will be reevaluated. Cases made of new lightweight materials will be tested and introduced into operation; already, these lightweight graphite fiber-epoxy composite cases have demonstrated high strength, moderate cost, and reliability. And for smaller rockets, development of a "hybrid" motor that combines solid fuel with a liquid oxidizer sprayed into the motor chamber would offer the shutoff/restart capability of a liquid-fuel motor with some of the solid's simplicity.

We may see colossal solid-fuel boosters that produce more than nine million pounds of thrust for use in launching space-station components and future manned and unmanned planetary missions. The advantages of the solid-fuel rocket booster—simplicity, reliability, and low cost—will persist as humankind's oldest form of reaction propulsion becomes more capable and sophisticated.

A REPAIR SHOP LIKE NO PLACE ON EARTH.

In low orbits around the Earth, satellites gather, analyze and transmit critical information–for scientists, for corporations, for countries.

Because of the high cost of getting them up there in the first place, some of these satellites are designed to be repaired where they are if something goes wrong.

A manned space station could act as the neighborhood garage –the local spare parts and repair facility for these valuable satellites. That's one reason why McDonnell Douglas is working to put a space station in orbit by the 1990s.

Since 1960, when we did the first Manned Orbiting Research Laboratory studies, we've been a world leader in space systems. We built the original space station–Skylab. And we've been a pioneer in space systems operations, from launches to payload integration.

Now we're devoting our space experience, systems expertise, and technological ingenuity to taking America the next step into space–with a manned station.

Such a station could lower the cost of technological upkeep–for science, for industry. We think that's a very good reason to build a repair shop like no place on Earth.

MCDONNELL DOUGLAS

Essay

The Great American Pilot Shortage

It's the next national deficit the United States will be forced to face.

By Steven Thompson

All major airlines in the United States soon will be faced with a crisis: they will be losing pilots at a rate faster than they can replace them. There was a time when people would give their eyeteeth to become an airline pilot, but those days seem to be over. You'd think that today, when America's youth seems to prefer a good job over a good cause, the thousands of unfilled jobs in aviation would incite a stampede into flight training. You'd think so. But you'd be wrong.

In fact, the entire population of pilots in the United States—including both professional and recreational pilots—has been aging and shrinking, and both trends show no sign of slowing down. And while that big picture may be worrisome, a shortage of airline pilots is downright critical. The Future Aviation Professionals of America estimates that more than 8,000 new airline pilots were hired in 1985 alone and that during each of the next 14 years, more than 2,000 pilots will retire at age 60. To replace them, airlines have already begun to reduce entry standards for experience, education, and fitness.

According to Federal Aviation Administration (FAA) records, the average "active pilot" (holding a current medical certificate) was four years older in 1984 (the most recent year for which the figures are available) than in 1970, and the pilot population dropped from just under 733,000 in 1970 to about 709,000 in 1985. The picture is even bleaker if you look at what happened during this period: there was actually a steady gain during the 1970s, and the number of pilots peaked at just over 827,000 in 1980—but then began a long, steep slide. Thus, it took ten years to nurture, train, and license 94,000 new pilots but only five years to lose 118,000 old pilots.

There's more to the situation than simple supply and demand. Pilots are not consumer products; they're people who work hard, bear many burdens, and pay a high price for their certificates. They are also a national resource, important not just because of the critical job they perform but because of what they symbolize for our society: they are a persistent human presence in an increasingly automated industry. Simply put, we are willing to fly because up front, running the machine, there is a fellow human being in whom we place our trust. So when their numbers change dramatically, we need to understand why and what it might mean for all of us, both as users of air transportation and as citizens.

All pilots are not equal, at least not in the eyes of the FAA. A series of ratings provides the means by which the FAA ensures that a pilot is qualified to fly a given airplane. Among the pilots themselves, the hierarchy of ratings becomes a series of career milestones and professional caste marks. The figures for active pilots cited here include all non-military pilots; refined to show the ***kinds*** of pilots in that declining population, 43.8 percent are private pilots, 21.3 percent are commercial pilots, 20.6 percent are students, 11.6 percent are airline pilots, and 2.4 percent are classified as "other." Implicit in this hierarchy is upward mobility; a student pilot, given sufficient motivation, "tuition" money, and health, can aspire to become an airline captain by progressing, via training and accumulated experience, through a private certificate, commercial rating, and finally, the airline-pilot rating.

For years, the airlines have relied on this continuous progression, along with the constant infusion of military pilots, to supply them with professional pilots. The shortage of professional pilots, while apparently sudden, is the result of a gradual but relentless disruption of that natural progression. Two factors are at work: the number of student pilots starting civil flight training has declined even further and faster than the decline of the pilot population as a whole, and more of our military aviators are remaining in the military.

Pilot recruiting for the military services may tell us what's happening—or not happening—in the civil pilot world. In U.S. colleges and universities, the services aggressively persuade students to become officers by funding their education through the Reserve Officer Training Corps. Even without the recent

return of the cinematic fighter jock as hero (Tom Cruise's Navy pilot in *Top Gun*), military aviation has sustained a presence among students as an option—albeit a tough one—after graduation. Consequently, none of the services has difficulty attracting pilot candidates. Nothing like this system exists in the United States for civil aviation. But it once did.

Not long before World War II, U.S. military and civilian aviation leaders, fearful that war was inevitable and alarmed at the dearth of pilots, persuaded the Roosevelt Administration to train thousands of civilians to fly. The Civilian Pilot Training Program was hugely successful and instrumental in meeting the ultimate demand for all kinds of pilots.

Some members of the aviation community view the current shortage of pilots with an almost wartime sense of alarm. The leaders of the Aircraft Owners and Pilots Association (AOPA), a group formed in 1939 that has become the largest association of pilots in the world, consider the plummeting professional pilot population to a be a significant national threat. In response, they have proposed to members of Congress and the Reagan Administration that some aspects of the wartime training scheme be reactivated in the form of a plan they call the National Pilot Training (NPT) program.

"The NPT program," states the AOPA white paper, "would be administered as a series of flight training 'scholarships' to students already enrolled at two- and four-year institutions in the United States. The object of their training would be to take them from a nonpilot status through qualification as commercial pilots with instrument ratings." The AOPA suggests that the money for the program would come from the huge surplus

Today's students are still fired by the ageless dream of flight... but they think, mistakenly, that aviation offers no jobs. And that scares many of them off.

in the Aviation Trust Fund, which is up for renewal next year. The Trust Fund, funded from taxes on airfares and fuel sales, is intended for air transportation system improvements. The cost per student is an estimated $20,000, and AOPA's management believes use of Trust Fund money to cover that cost is necessary because, "If more people cannot be encouraged to join the ranks of pilots and, more specifically, professional pilots, then the air transportation system will be unnaturally constrained."

That "constraint" concerns the AOPA not only because it might adversely affect its members but also because it affects air safety. There is a growing perception that airlines of all sizes may be hiring pilots with too little experience. And in 1985, for the first time since World War II, the majority of airline pilots hired came from civilian rather than military training backgrounds. In practical terms, this means that fewer of the new-hires have extensive experience. It is almost universally agreed in aviation that judgment saves lives, and that judgment derives not just from training but experience, so the pilot shortage is understood to be a threat to safety as well as an economic issue.

Pilots used to be the personification of progress. They were the men and women who provided our wings, moved us and our goods, defended our borders, and lifted our spirits with their feats of endurance, skill, and dedication. To be a pilot was to be an adventurer, to challenge a hostile environment and prevail. Pilots symbolized heroism and the highest aspirations of humanity. They were widely perceived as among our society's best and brightest, regarded as role models, and when pilots evolved into astronauts, they became true national heroes. So it is tempting to lay the blame for the decline of the pilot population on an erosion of respect for pilots as symbols, and further, to wonder if that erosion signals some change in the nation's values, perhaps linked to a failure of collective nerve, a flagging of spirit, even a diminution in our capacity as individuals to accept responsibility. At any airport in the country, you can hear old pilots grumble that the Age of the Pilot is past, that kids don't care about flying any more, and that the reason is simple: the rewards are gone.

And yet Arthur M. Saddoris, Associate Director of Career Development at the University of Maryland, says that he and his office are besieged by students who "love flying, love space, love anything to do with technology or aviation, from a hang glider to the space shuttle." His view is echoed by other university career counselors across the nation and underscored by the lack of difficulty that colleges specializing in aerospace have in filling their classes. Listen to people like Saddoris and you hear that today's college students are still fired by the ageless inner flame of flight... *but.* But they think there are no jobs in the field. They, unlike their immediate predecessors, are highly job-oriented—cheerful, optimistic about the future, but pragmatic. According to Saddoris and his colleagues, aviation simply scares many of them off. And even if they do try to pursue their fragile, youthful hopes, they have a hard time getting "access"—access to airplanes and to airfields. (Next time you're at a local airport, see if *you* can find the front door.)

When you talk with the likes of Louis Smith, president of Future Aviation Professionals of America, you hear about unfilled cockpit seats, about the dramatic shortage of career pilots—indeed, shortages in *every* skill relating to aviation—that the AOPA cites as the rationale for its National Pilot Training program. When you ask if the students know about this, Smith says, "Oh, no. Academia doesn't have the word yet." And when you talk with college career counselors, you realize that they seem indeed not to have gotten the word. And then you wonder if the whole pilot shortage is not really a question of shifted societal values but simply a case of a colossal failure to communicate.

If so, and if there is value to us all in having a robust and continually reinvigorated aviation culture, then you are left with two conclusions. The first is that the aging and shrinking of our pilot population *is* a matter of national concern. And the second is that, in light of the inaction of the rest of the aviation community, the AOPA National Pilot Training proposal deserves the closest scrutiny by the Administration and the Congress for inclusion in the Aviation Trust Fund legislation—not just because the program can train, but because it can communicate. And sometimes communication is more important than training, for without the former, there is all too often no need for the latter.

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A car you can believe in.

By Junius Ellis

By now, most people are aware of a strange aircraft called *Voyager.* In flight, it is one of the most astonishing sights in the history of aviation. The airplane's proportions seem preposterous. Its thin wings have the span of a Boeing 727, yet it weighs less than a small car. In mid-July, it set off from Mojave, California, carrying pilots Dick Rutan and Jeana Yeager on an aerial endurance test of more than four days flying a circuit off the coast of California. *Voyager* returned to Mojave to set a world nonstop, closed-course distance record of 11,600 miles aloft.

The mid-summer flight of this remarkable airplane and the grueling ordeal its two pilots underwent was merely a warm-up for the main event: a flight that would circle the globe without once stopping or refueling. The 25,500-mile journey will be flown at an average speed of less than 100 mph and will take 12 days to complete. For its round-the-world trip, *Voyager* will depart from Edwards Air Force Base, only a 10-mile hop from the airplane's home airport at Mojave. The trip is scheduled to start in mid-September, but if necessary, could be delayed into November.

Strange, experimental aircraft are stock in trade at Edwards, the sun-parched testing grounds for such historic flights as the successful assault on the sound barrier by XS-1 pilot Chuck Yeager (no relation to Jeana) in 1947

VOYAGER

Never have so few tried so much with so little.

Rutan-Yeager

Voyager*'s unusual shape has a purpose: it spreads the 9,000-pound weight of the airplane's fuel load (left).*

Pilots Dick Rutan and Jeana Yeager have to be best friends to survive 12 days in the passenger cabin (above).


N66433

and the first touchdown of the space shuttle in 1981. But Edwards has witnessed no aircraft as ungainly as this three-pronged flying fuel tank that carries 9,000 pounds of gasoline—five times the airplane's own weight. That should be enough fuel for Rutan and Yeager to complete their unprecedented odyssey and claim a seemingly unattainable aviation record.

In fact, *Voyager* may be the first aircraft capable of undertaking such a perilous journey, though a number of unsuccessful machines designed for other attempts at the feat preceded it. Designed by Burt Rutan, Dick's younger brother and the acclaimed creator of a new breed of airplanes designed to be built from plans and parts by their owners, *Voyager* is made of a honeycomb core material sandwiched between cloth-like sheets of graphite fibers embedded in plastic. This simple structure is stronger than steel at one-fifth the weight, which means the airplane can haul nearly 1,500 gallons of gasoline that's sipped slowly by two very efficient piston engines located fore and aft on the central fuselage.

Rutan's calling card as a designer has been his absolute adherence to the "canard" configuration: placing the horizontal stabilizer surfaces ahead of the airplane's wing. Although the configuration looks weird, it was used successfully by the Wright brothers and repeated by others from time to time. The design offers at least one advantage: unlike conventional airplanes' horizontal stabilizers, which are located at the tail and designed to provide a down-force, the canard provides additional lift, improving efficiency and range.

Voyager is piloted by two seasoned fliers who have spent five years building and flight-testing the airplane. They have endured long stretches aloft learning how to eat, sleep in a narrow bunk, and remain sane in a noisy, unpressurized cabin as snug as a small pup tent.

They have also studied the weather conditions in the tropics, through which much of the flight will pass, and have chosen to fly west over mostly open water to get a boost from the easterly trade winds near the equator.

They will tempt death to achieve what they believe will be the last major milestone in aviation's pioneering century. "If people like Charles Lindbergh hadn't risked death to advance technology, we'd still be crossing this continent looking over the asses of oxen," says Dick Rutan, 48, a gung-ho former Air Force fighter pilot who has long idolized Lindbergh, and who groomed girlfriend Jeana, 34, to be his first officer. "After the *Challenger* disaster," he says, "America needs something like *Voyager* to show the world that we aren't afraid to get things done."

The first round-the-world flight, launched three years before Lindbergh flew solo across the Atlantic in 1927, was a U.S. Army Air Service effort that involved four Douglas biplanes flying together and took 175 days to complete. The record for the longest nonstop, nonrefueled flight was set in 1962, when the crew of an Air Force B-52 bomber flew 12,532 miles, from Okinawa to Madrid. (The record *Voyager* broke in July was for the most miles logged in a closed circuit—a different category.) *Voyager* must break the 1962 record by more than 10,000 miles in its bid for what the Fédération Aeronautique Internationale in Paris calls the absolute nonstop, nonrefueled "speed around the world" title: a flight that equals or exceeds the 22,589.79-mile circumference of the Tropic of Cancer. The flight must also end where it begins, in this case at Edwards.

Rutan and Yeager plan to head west toward Hawaii, and down across the South Pacific, northern Australia, and the Indian Ocean, then around the Cape of Good Hope to the Atlantic. They'll turn north back across the equator, along the edge of South America to the Caribbean, the Gulf of Mexico, the Texas coast, New Mexico, Arizona, and home to Edwards. But the exact track they fly will vary in response to the

The instrument panel is compact but complete, with radios, weather radar, autopilot, and navigation computer.

Christopher Springmann

Rutan and Yeager will switch places at the controls, which requires tricky maneuvering in the cabin (below).

Mark Greenberg

For maximum fuel efficiency, Voyager *will use only its rear engine for most of its historic flight (left).*

Mark Greenberg

weather *Voyager* encounters.

If they make it, Rutan and Yeager can look forward to cashing in big on their instant celebrity status: TV commercials, book sales, maybe even a movie deal. They may also get a tax deduction for donating their airplane to the National Air and Space Museum, where Rutan hopes *Voyager* will be enshrined in the halls that hold such icons of aviation as the *Spirit of St. Louis.* "There's no honor higher than that," says Lindbergh fan Rutan. Should they fall short because of rough weather, mechanical failure, or pilot error, their chances of surviving a forced landing, almost certainly at sea, are perhaps better than those of the fragile airplane.

Corny as it may seem, Burt Rutan's original idea for *Voyager* was sketched out for Dick on a coffee-shop napkin in early 1981. "Once I realized that composite materials had made a world-circling attempt technically possible, I was hooked on the project as a designer," says the 43-year-old Burt. So was Dick as a pilot, provided Burt really was serious about allowing him to run the show. It was a difficult time of transition for the Rutan brothers—intense, strong-willed men who often disagree. Burt had begun work on the first of several big development contracts with Raytheon's Beech Aircraft, for whom he designed the Starship 1, a businessmen's turboprop (and a canard, of course). Dick, meanwhile, had recently met Jeana, moved in with her in Mojave, and walked out on Burt, his only employer since his retirement from the Air Force in 1978. "There was no bad blood between us," says Burt. "Dick bailed out because he just couldn't bear to work with people who looked up to his younger brother."

Sons of a dentist who owned a small airplane and encouraged them to learn to fly as teenagers, the Rutans grew up in Dinuba, California, near Fresno. But their flight paths to adulthood and separate hangars at Mojave Airport took decidedly different routes.

Dick, the hotshot, entered the Air Force right out of high school and earned his commission as a fighter-bomber pilot bound for Vietnam. From 1967 to 1968, he flew 325 combat missions before he was shot down by enemy fire and pulled out of the Gulf of Tonkin by a helicopter. Burt, the hacker, began

designing his first airplane, a two-seat canard called the VariViggen, while still a student at California Polytechnic State University. Then, in 1973, he founded the Rutan Aircraft Factory at Mojave to sell VariViggen plans to like-minded enthusiasts. Next came a series of canard airplanes: the VariEze, Long-EZ, and Defiant. His designs earned him wide recognition in places like the Pentagon and the National Aeronautics and Space Administration, for whom he has done contract work.

As Burt's business and reputation took off, Dick's career as a military pilot stalled. After 20 years in the service, stuck at a desk job, he retired as a lieutenant colonel and went to work as Burt's chief test pilot. It seemed to be an ideal job for Dick, who spent much of his time at air shows performing in his brother's airplanes. It was at one show—in Chino, California, in 1980—that he met Jeana, a draftsman, fledgling pilot, and admirer of Rutan designs.

At a speed of less than 100 mph, Voyager *flies into the record books at a slow but stately pace (left).*

Petite in size and even shorter with words, the Texas-raised Jeana had recently been laid off by her boss and mentor, rocket pioneer Robert Truax. After spending nearly two years promoting and picking up after Truax's Project Private Enterprise, a now moribund venture to launch paying passengers briefly into space aboard a reusable 25-foot rocket, Jeana was ready when Dick said he could line up work for her at Mojave. She also proved to have records in mind: under Dick's tutelage, she set four aviation world records and went on to break one of his.

The deal that the Rutan brothers struck in 1981 culminated in Voyager Aircraft Inc., founded by Dick and Jeana with $10,000 they scraped together at the time. The firm's principal expense was rent on a hangar at Mojave Airport and its main liability a contract, still outstanding, for Burt's design work.

Armed with his brother's preliminary plans, Dick tried to line up corporate sponsors willing to put up the estimated $550,000 needed to build *Voyager.* But none was ever found, for reasons that boil down to Dick's refusal to share control of the project. There was also the

Mark Greenberg

La nouvelle cuisine *it's not, but Rutan has learned from experience that long flights dull the appetite.*

Dick Rutan

Yeager hopes long hours over the ocean in the noisy cockpit will prove to be a peaceful time.

high risk of failure. Sniffs Dick: "Executives were afraid to put their company's logo on an unproven airplane that might crash in a fireball and land them in the hot seat." His case was undermined further in 1982 by a fatal crash at Mojave during a test of another round-the-world airplane that had been unveiled soon after the *Voyager* effort began.

Voyager's lack of progress also had gained Burt's attention. In late 1982, he says, "I told them I'd finance the construction myself, with Dick and Jeana doing most of the work. Fortunately, I was able to talk my suppliers into donating most of the materials and parts." Altogether, Burt says he funneled about $200,000 into the project before *Voyager*'s roll-out press conference in June 1984. Dick and Jeana also launched a grass-roots fund-raising campaign that netted them more modest contributions from people all over the country. Since then, the mere presence of *Voyager* in the hangar and over Mojave has eased Dick's search for companies eager to donate costly components (engines and avionics), services (chase airplanes and legal counsel), and supplies (fuel, oil, and food). Major cash contributions, however, continued to be scarce.

The airplane certainly commands attention, with its central fuselage suspended between twin fuel "outriggers" attached to the flexible main wing and, near the nose, the shorter canard wing. Burt made the main wing narrow and long to enhance efficiency and range. The outriggers provide support for the main wing and anchor a fuel-distribution system that must be tended periodically to maintain optimum trim and keep the airplane in balance to minimize drag.

Voyager's front engine pulls and its rear one pushes. Both are needed for takeoff and the first third of the round-the-world flight, during which the airplane, consuming roughly half its fuel, climbs up to 15,000 feet. At this point, the front engine is shut down for the remainder of the flight to conserve fuel and serve as a backup. With only half power, *Voyager* will slowly descend, level off at 10,000 feet and then start to climb again as its fuel load lightens and weather conditions warrant. During the final third of the flight, it can ascend to catch a tailwind or pass over a rough storm. The airplane carries enough supplemental oxygen for four or five days, depending on the altitude.

Mark Greenberg

Dick, left, and Burt Rutan took different paths to aviation careers, only to be united by Voyager *(above).*

The aerodynamic refinements that give *Voyager* round-the-world range also make it a beast to fly. Indeed, Dick and Jeana joke that the airplane handles like a pterodactyl—a reference to Paul MacCready's mechanical replica of that winged reptile—because of its marked tendency to heave and lurch in choppy winds. "Coping with motion sickness has been a problem, particularly for the off-duty pilot, who's stuck lying down in a bunk," Jeana says. Adding to this discomfort is a crude method of human-waste disposal (plastic bags that are jettisoned) that's unwieldy under the best of circumstances.

The flexible, featherweight *Voyager*'s nettlesome sensitivity to turbulence was a major factor in charting a westbound course primarily over water, where the air is relatively smooth compared with the boisterous thermals common over land masses. There were political considerations as well. By flying over international waters for most of the flight, *Voyager*'s crew won't have to worry about requesting clearances from various nations' authorities whenever they need to alter course to avoid or take advantage of particular weather patterns. On the other hand, over water they can't be assured of receiving prompt responses to mayday signals should they be forced down far from land. "I'd rather run the risk of ditching, which is pretty unlikely, than have my route options restricted by some air traffic controller," Dick says. Just in case, *Voyager* is equipped with an inflatable life raft and a hand-held transmitter that's linked to a position-fixing satellite rescue network.

Data from three weather satellites high above *Voyager*'s route will be fed to the crew via short-wave radio by volunteer meteorologists manning the mission control center in Mojave. Housed in

Mark Greenberg

Voyager had trouble finding sponsors, but firms eventually gave radios, materials, and engines (right).

a rented trailer, the center has both a hotline to the National Oceanic and Atmospheric Administration's computer in Bethesda, Maryland, and one of those colorful, computer-animated weather monitors now standard on TV newscasts. As an extra precaution, Dick insisted on *Voyager*'s having a small weather radar unit despite Burt's objections that the equipment isn't worth the added weight and wiring. Dick believes that onboard radar can be a "life-and-death necessity at night," particularly over the Pacific, where violent thunderstorms can pop up suddenly.

Dick learned about the subtleties of worldwide weather back in the Air Force. He is also no stranger to the insidious cockpit fatigue that can cloud an aviator's judgment, curb his appetite, and create bogeymen to ease the boredom. One such little man appeared on the canard of Dick's airplane in 1979, when he spent almost 34 hours aloft to set a 4,800-mile world closed-course record in his brother's Long-EZ. "We had a lucid conversation. It scared the hell out of me," he says.

Twelve days in *Voyager*'s tiny cockpit and bunk leave a lot of room for the imagination. A flight surgeon has planned for the daily physical needs of each crew member: alternating six-hour shifts at the controls; one low-fat, high-carbohydrate main meal supplemented with snacks; three liters of water; oxygen; and medication, if necessary, for motion sickness, insomnia, and constipation. But nobody knows how, or whether, the pilots will cope with mounting fatigue and cabin fever. Dick claims he and Jeana will be too busy piloting and navigating to dwell on the question. But Jeana, who has already given it some thought, says, "Compared with the headaches we've had so far, the flight could be quite peaceful. Problems on the ground can't intrude, except on the radio. And it has an off button."

But when the airplane has taken off from its starting line at Edwards, you can imagine only those two people, alone, and an ocean.

It's a bird, it's a plane, it's Expo 86. It's also rockets, space rides, UFO-H_2Os, and lunar rovers.

Air at the Fair

By Daniel Jack Chasan

Photographs by Nick Gunderson

You can't help noticing all those orange-and-white checked windsocks billowing straight out, that striped hot air balloon, the array of propellers whirling in the wind. Even before you pass through the gate to Expo 86—the world's fair now under way in Vancouver, British Columbia—you see them floating and fluttering in the sky.

It's an appropriate introduction, because once inside, you're constantly looking *up*. You look up at flags and banners and monorails; up through the ubiquitous multistory lattices of bright steel tubing. You look up to see what casts that shadow approaching swiftly like some large predatory bird (it's only the gondola of a skyride). You look up at the Space Tower ride that lifts the adventurous 236 feet into the air and drops them in a controlled free fall, and up to see stomachs being churned by the Looping Starship, a hyperactive, slightly bent "space shuttle" that seats screaming kids ten abreast.

Want a Big Mac? The golden arches are diminutive, but look to the rooftops for a stylized rocket marking McDonald's. Some nachos? Buy them from the guy in the space capsule, which looks like it's ready to go up at any moment.

Indeed, capsules appear in the oddest places. Try Highway 86, a 240-yard-long undulating ribbon of concrete on which various gray-painted vehicles are stuck like flies on flypaper. Many are of the everyday sort: a Mercury station wagon with luggage on top, a bicycle, a float plane, a Volkswagen Beetle, an old Mustang convertible with its top down and a surfboard in the back seat. Kids clamber over scooters and motorcycles. For a dash of the exotic, there's a lunar rover and a submarine. And back near the Mustang stands an old Ford flatbed truck carrying—you guessed it—a Gemini space capsule.

"Highway 86" forms a testimonial to transportation (left). Even a 747 jetliner made an appearance—sort of—at the fair (above).

Because Expo 86 is a world's fair sanctioned by the International Bureau of Exhibitions, the Paris-based group that sets standards for such things, it needed a theme. Expo's management chose transportation and communications, reflected by the slogan "World in Motion—World in Touch." But the content of each exhibit was left to the participating nations, states, provinces, territories, and companies, and it seems that every exhibitor with a presence in space has chosen to flaunt it.

The United States, for example, displays nothing else in its pavilion. A photo gallery of astronauts greets you upon entering. Then you encounter Mercury and Gemini space capsules, Viking and Voyager space probes, and video screens featuring Jupiter and Saturn flybys and the Apollo astronauts in action. But the really big show is a movie of the shuttle taking off, complete with rumbling rocket noises—you see it going up, get an astronaut's-eye view of the Earth, hear conversation with mission controllers in Houston. You get a spectacular view of space, too, and see the crew working, weightless in the cabin. The final scene is of a space station turning, turning out in the void, imparting a sense of technology as ballet. By the time you leave the pavilion, the message is clear: space is us.

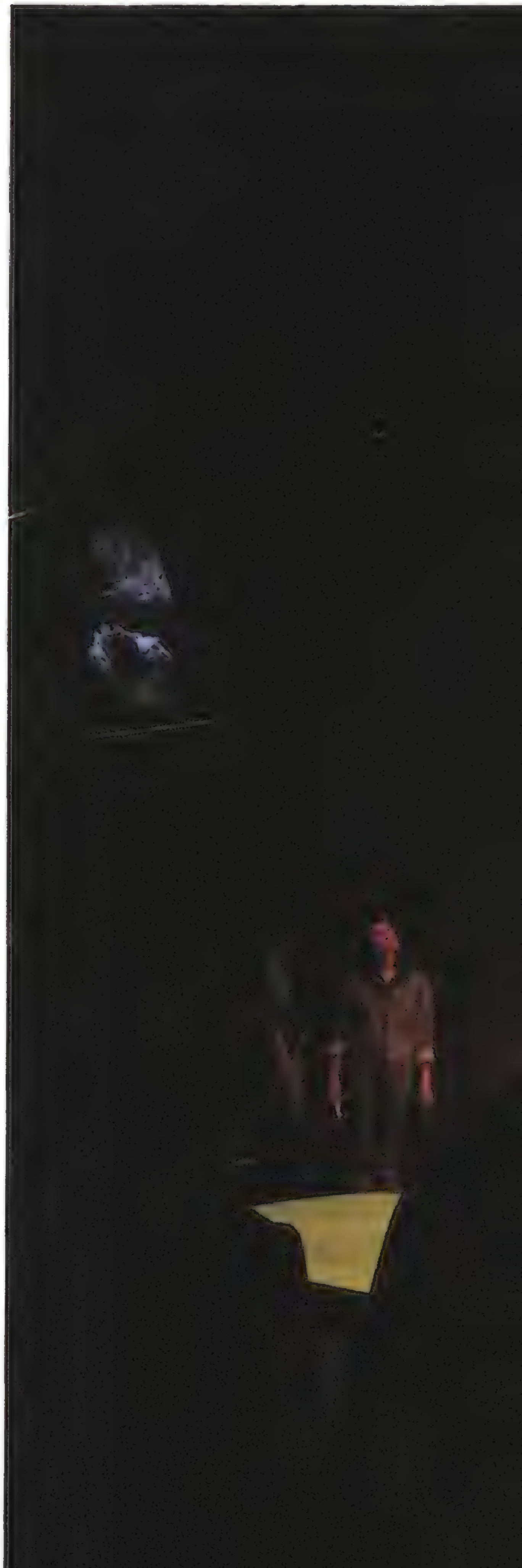
Towering over the Soviet Union's pavilion is a silver statue of Yuri Gagarin: the first man in space stands with arms upraised, a trace of a smile on his lips, streamers flowing out behind him. A crowd waits to enter a scale-model Sal-

In the U.S. pavilion, a mannequin astronaut symbolizes the quick hop between Earth and its moon.

yut space lab, which stands nose-to-nose with a Soyuz spacecraft like those that ferry cosmonauts into orbit. In line are kids, grandparents, young couples, a guy wearing a jacket advertising "barnstorming." As at most pavilions, they have the patient, dutiful air of people about to undergo an educational experience. Once inside, though, their resignation becomes curiosity as they gaze at the cockpit, with its impressive ganglia of wires, and at the tubes and small cans that hold cosmonauts' food. They point at the exercise bike on the cockpit ceiling and ask each other how the shower works.

Canada's pavilion is more low-key, but even here space achievements tend to command center stage. There's a model of the "Canadarm," a device resembling a large dentist's drill that fits into the shuttle's cargo bay and is used to manipulate satellites and other objects in space, and a film of the arm in action. (The Canadians plan to build a

In a hall of larger-than-life crystals, visitors learn why space is ideal for producing the real thing (above).



Youngsters become spacecraft "pilots" in this interactive video game, a trip to the future in the here and now (right).

bigger, more sophisticated version dubbed "Smartarm," which will be called upon when the time comes to build and service the space station.)

To show off the Canadian landscape, there is a film that provides a pilot's-eye view from a float plane. The aircraft takes off from a remote lake and flies low over the wilderness. You zoom over hills and buttes—the queasy are advised to look away. You look down on bison running across the plains, on wild horses running across the sands of Sable Island. (Why are they all running? Because somebody's chasing them in a low-flying aircraft, that's why.)

For the strongest sense of place and time, though, forget the big national shows and go to Air Canada's pavilion. The room is almost dark when you walk in, and all you see are metallic glints from a twin-engine Lockheed 10A Electra, one of the airplanes with which Air Canada started service in 1937. You're aware of the gleaming surface, of the curves, of the unseen remainder of the airplane. It's aircraft as sculpture. But the tone is by no means reverential—in the background you hear snippets from the late 1930s: songs in English and French, radio shows such as "The Shadow" and "Mark Trail," and commercials for Pepsi and Philip Morris.

As a space vehicle, UFO-H2O is unsafe at any speed. As a water fountain, kids find that it's just right.

Then the show starts. You're in the airplane's cockpit, looking at the instrument panel as the pilot runs through the usual preflight checklist. Suddenly the engines seemingly roar to life, with strobe lights and booming sound effects, and you take off into the night. After the show, which includes a mock lightning storm that's amazingly realistic, the audience claps and cheers.

Out in the daylight, in 1986, you can watch kids get soaked by the UFO-H_2O, a hokey flying saucer, topped by the head of a little green man, that features a jumble of water fountains. Each fountain spurts at unpredictable intervals—accompanied by watery electronic beeps and gurgles—so the kids never know which one will go off when. The more determined kids stand over the nozzles, waiting to catch a spurt. Others wander among the fountains, picking—or becoming—targets of opportunity.

While it might be tempting to describe a flying-saucer fountain as "futuristic," it wouldn't be quite right. After all, these kids in sopping T-shirts have grown up with the notion that space flight—if not little green men zipping about in tiny saucers—is real. Space is familiar; it's like a slightly distant part of their own neighborhood.

Indeed, Expo 86 doesn't offer much wide-eyed futurism in the manner of some past world's fairs. Space travel, for example, tends to come off as history. Yuri Gagarin made his flight more than 25 years ago. The astronauts' pictures in the U.S. pavilion have the retrospective quality of photographs on a high school wall. The kids who watch films of humans walking on the moon are seeing something that happened before they were born.

And if space seems familiar, aviation is made even more so. No spotlights linger, for example, on the jetliners that schlep many of us from place to place every day. Of course, it would have been a wee bit difficult to get, say, a full-fledged Boeing 747 into the heart of Vancouver. However, the nose of a 747 did make it, brought by boat up False Creek, an inlet of the Pacific Ocean that flanks much of the fairground. The jetliner, located in what's designated as the Air Plaza, dwarfs the other aircraft on display. Its front wheels alone stand as high as the canopies of the fragile ultralights scattered nearby. It is a condor among hummingbirds.

Across the plaza sits a dragonfly-like aircraft with wings made of translucent

The Space Tower ride drops its daring passengers 120 feet in six adrenalin-packed seconds of free fall.

It's history on parade, with an airborne queen leading the way, as fairgoers go about their affairs.


G-CAHR

The nachos and salsa may be down-to-earth, but the concession stand is surely ready for orbit.

cloth stretched over a bamboo frame. This delicate creature is a replica of the Pearse airplane that, a placard says, was "reported to have carried its owner aloft several times between 1902 and 1903." The Wrights flew at Kitty Hawk on December 17, 1903. Where was Richard Pearse? In New Zealand.

Nearby is the sole surviving Boeing 80A Trimotor, a 1929 biplane that was the first aircraft to offer stewardess service. From its three radial engines to the three wire-linked rudders of the triple tail, the airplane has a functional, almost stripped-down, appearance. Looking ready to go, a fool-the-eye figure of a typical passenger, decked out in 1930s suit and snap-brim hat, hands his ticket to a stewardess, while a mannequin mechanic works on the airplane's starboard engine.

The 80A shares space with a sleek, red Aerocar, a flying automobile designed 36 years ago by Molt Taylor of Longview, Washington, and certified by the Federal Aviation Administration. With its compact car body, broad silvery wings, and single rear-mounted propeller, the Aerocar is like a Honda's dream of glory come true.

Suspended from girders overhead, in something of an imaginative hangar, is a procession of aircraft from history and fantasy. There's the hot air balloon that's visible from outside the grounds and a gaudy little zeppelin. There's a galleon (from the days when ships were the only way to "fly" across the seas), and there's even a figure of Icarus, heading foolishly for the sun.

The assemblage forms a huge stabile of airborne motion. And its whimsy finds an echo in Canada's pavilion, where a helium-filled saucer, guided by remote control, wanders gently through the air under the sail-like cloth roof. Off to one side, a pair of skeletal metal wings flaps up and down, up and down.

This perpetual motion, this less-than-utilitarian movement, takes place in different forms all over the fairground. The windsocks, the banners, the wind chimes tinkling outside the Korean pavilion, the propellers turning this way and that are always in motion but going nowhere. The constant fluttering seems to carry a subversive message: hold the rockets, hold the latest jets, hold those wonderful old airplanes. The real star of this show is the wind.

Fairgoers can't get enough of the Soviet Union's Salyut spacelab—a favorite Expo attraction.

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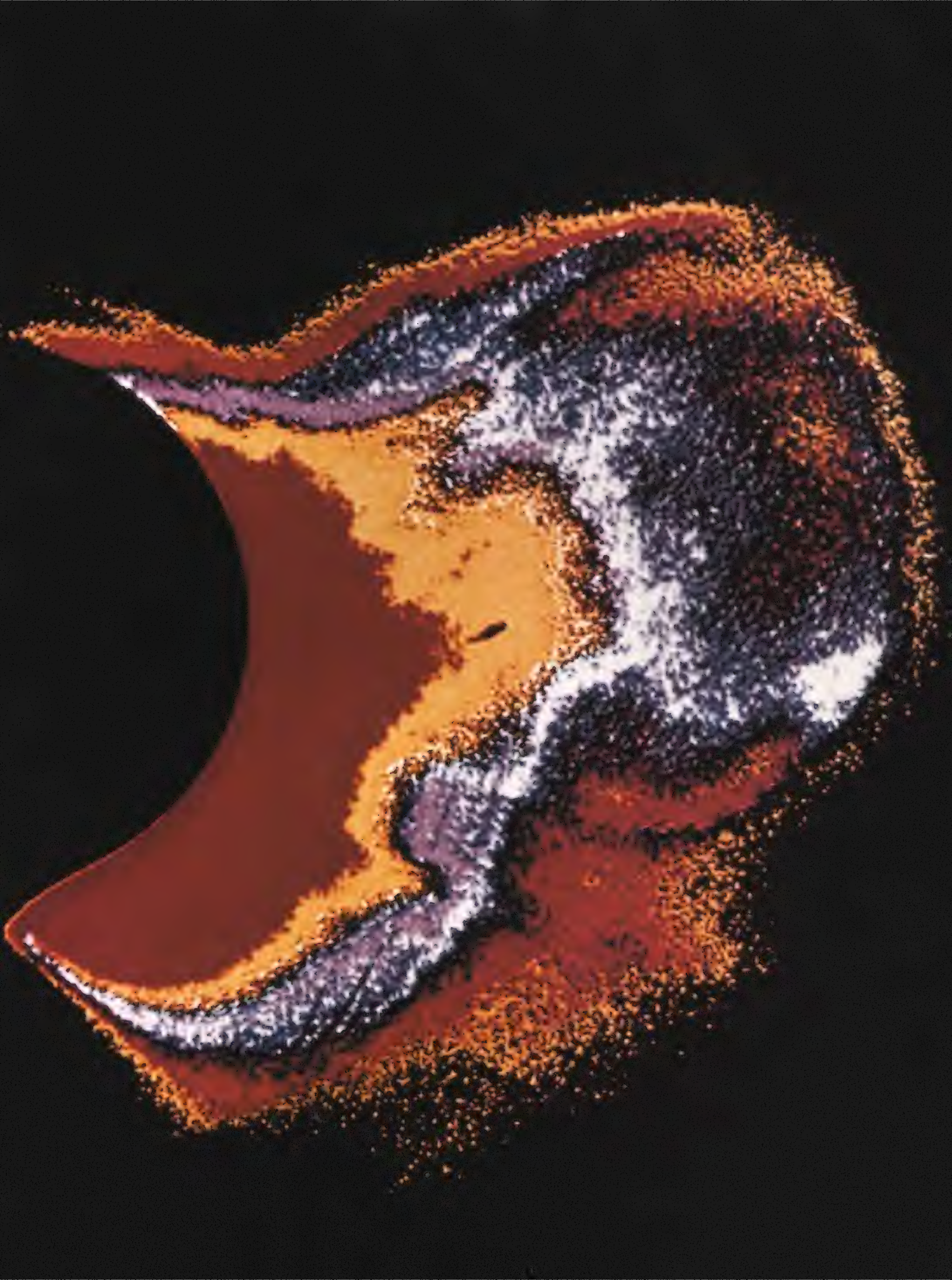
Here's Looking at You, Sol

Sophisticated spacecraft and powerful telescopes provide new insights into the behavior of our stellar neighbor.



By Randall Black

Although humanity's fate is inextricably linked to the sun's continuous outpouring of warmth and light, we know surprisingly little about our parent star. It's the source of virtually all the energy that powers our planet (radioactive decay and tidal flow make up the rest). A spark from the sun's thermonuclear fire resides in every morsel of food we eat, every ounce of fuel we burn. But only recently have we begun to understand Old Sol, as an army of solar scientists monitors its behavior using powerful telescopes, highly sensitive instruments, and viewing platforms in space.

Of all the advances in solar science, the most significant has

Paul Chesley

Solar researchers would be hard-pressed to decipher the flood of raw data relayed by satellites were it not for a Cray supercomputer at the National Center for Atmospheric Research in Boulder, Colorado (right).

Pages 82-83: Skylab, *equipped with a special telescope that creates its own solar eclipse, provided scientists with this image of the sun's halo-like corona.* High Altitude Observatory

been the advent of space-based observations that capture wavelengths of light that can't penetrate Earth's atmosphere. According to Jack Eddy, a solar physicist at the University Corporation for Atmospheric Research in Boulder, Colorado, the launching of a spectrograph aboard a V-2 rocket in October of 1946 marked a major turning point. ("Richard Tousey and His Beady-Eyed V-2s," June/July.) "That step forty years ago changed everything," Eddy says. "If someone were to ask me to name the biggest event in solar physics in the last fifty years, I'd say it probably was that first glimpse of the sun in these wavelengths that had always been hidden from us." Viewed from the Earth's surface in visible light, the sun appears relatively peaceful, but ultraviolet and X-ray observations made from space reveal an awesomely turbulent sphere.

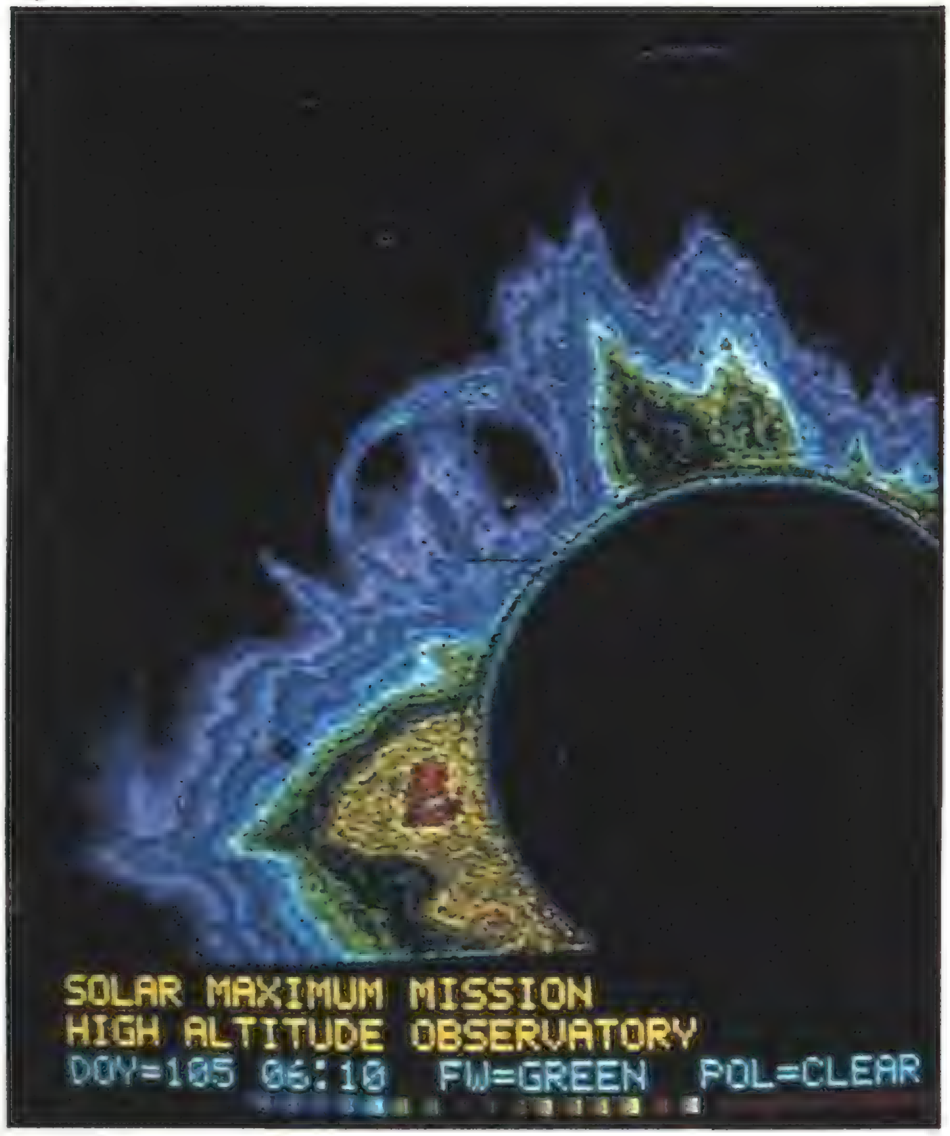
Solar physicists also value their access to space for the new vantage points made available. Within the next few years, for example, the European Space Agency and the National Aeronautics and Space Administration (NASA) will send a spacecraft called *Ulysses* out of the solar "ecliptic plane," the imaginary disk around the sun's equator in which all the planets except Pluto orbit, and over the sun's poles. *Ulysses* can't fly directly from Earth to circle the solar poles—no existing

rocket can provide enough power—so the spacecraft will first journey to Jupiter, where the giant planet's powerful gravitational field will hurl it out of the ecliptic plane.

Ulysses is in storage until a launcher becomes available; but once the spacecraft gets going, it will take 14 months to reach Jupiter. After circling the planet and being shot back toward the sun along a route well below the ecliptic plane, the spacecraft will take 28 months to arrive at its destination. (This circuitous route is reminiscent of the winding journey of its namesake: Homer's hero in the epic *Odyssey.*) *Ulysses* will fly over the sun's south pole at a height of 186 million miles—twice the distance from Earth to the sun—then continue on its orbit and, nine months later, pass over the sun's north pole. Its primary mission will be complete and its power generator probably will be running out of juice. But project scientists hope *Ulysses* will survive for an encore, making another journey of six and a half years out past Jupiter and back to observe the sun a second time.

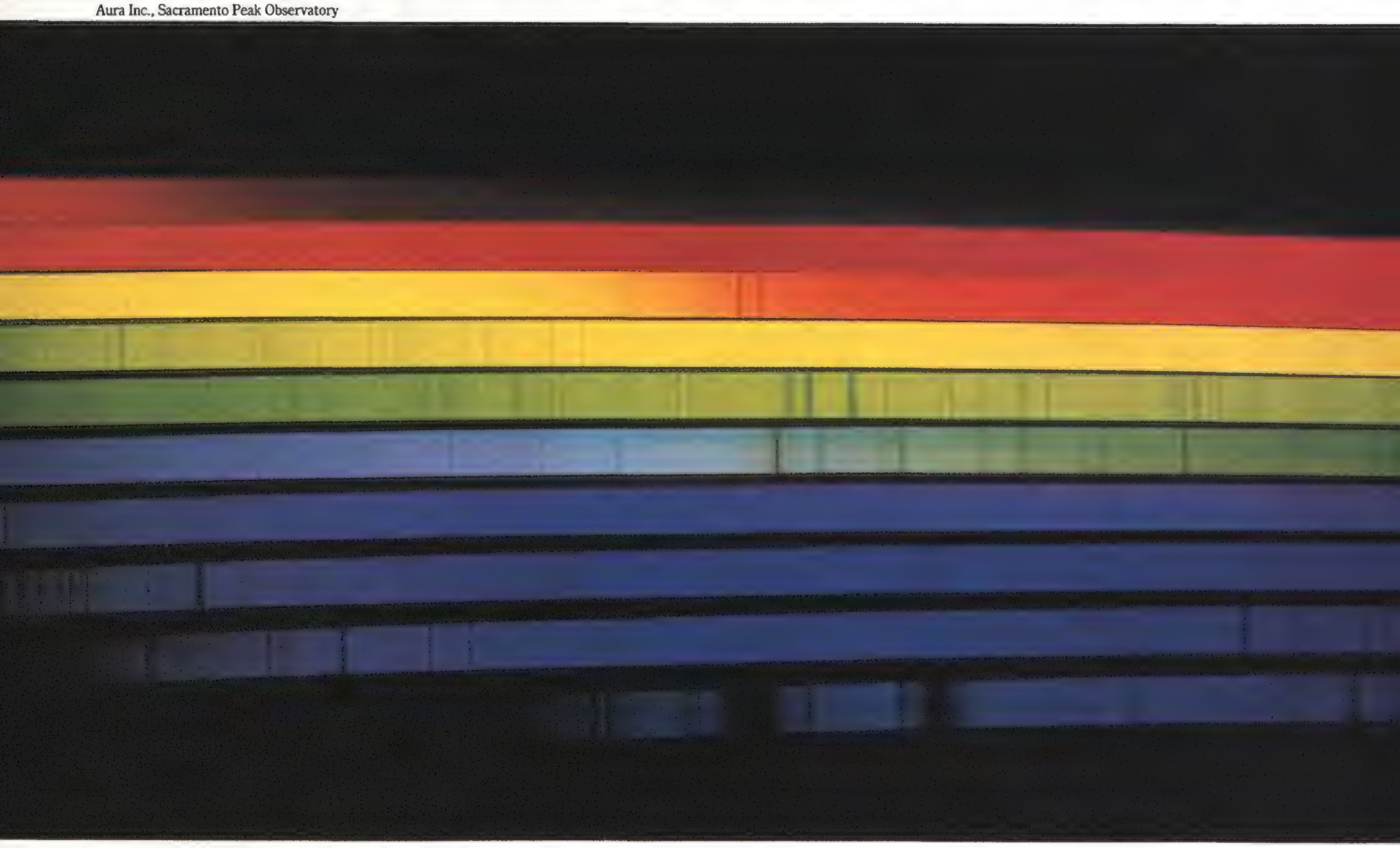
Ulysses should yield badly needed information about the sun's magnetic structure, which is linked to a variety of phenomena. Sunspots, solar flares (which can disrupt radio communication on Earth), the "solar wind" that streams steadily out into the solar system, possibly even changes in luminosity—all dance to the tune of the sun's magnetic activity. The magnetic field originates in the sun's core, which acts like a huge dynamo, generating powerful field lines that envelope the blazing orb. Earthbound astronomers, viewing the sun's

High Altitude Observatory



Images of solar "hiccups" from the satellite Solar Max *may help explain the sun's influence on Earth (above).*

Aura Inc., Sacramento Peak Observatory



NASA

Repairing Solar Max *in orbit from the space shuttle in 1984 added years to its mission life. It will begin monitoring the sun's next magnetic flare-up in two years (above).*

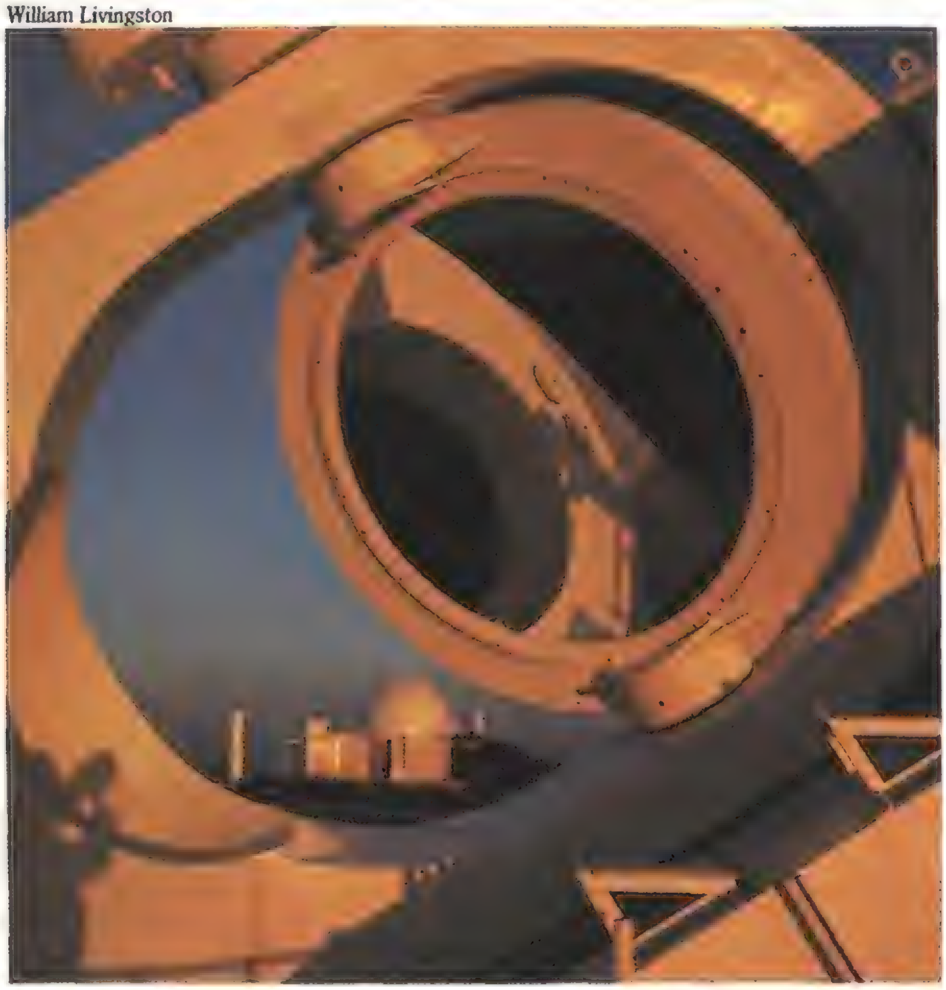
Working with the knowledge that light betrays the composition of its source, scientists use spectrographs to break down sunlight into its component parts (left).

equatorial region from the ecliptic plane, see a tangled mess of twisted field lines and a buzzing array of solar particles. Some of the particles are electrically charged bits of atoms, called ions, that the sun spews out through holes in its halo-like corona. These low-energy particles form the solar wind, which pushes at the lines of magnetic force, stretching and finally breaking them as the wind escapes the sun's gravitational pull. Higher-energy particles from the sun also mix with the field lines, corkscrewing around them like moths around a light.

As the sun rotates, its magnetic field lines coil around it like a watch spring. Rotation knots up the solar wind, too, so a complete picture of what's happening gets rather complicated. The solar wind rushes from the sun in both fast and slow streams. A slow stream exits a coronal hole, the hole then rotates and lets loose a fast stream of particles, and finally, the fast particles catch up with the slower ones in a roiling pileup. The solar physicist's job of sorting out field lines and particles in the sun's equatorial zone is something like trying to untie a shoelace that's attached to a blender set on "puree."

The picture should clear up, however, with help from the polar-orbiting *Ulysses.* "We believe the situation over the poles will be quite different from that at the sun's equator," says Edward J. Smith, U.S. project scientist for *Ulysses.* "We

William Livingston



Gary Ladd

Visitors (lower right) to Kitt Peak see the sun reflected by the mirror of the McMath telescope (above).

Aura Inc., Kitt Peak National Observatory

expect to find a steady solar wind blowing without a lot of interaction, and the magnetic field lines should tend to be essentially straight." Because these field lines will extend away from the solar poles like needles in a pincushion, particles from the sun will travel outward virtually parallel to the lines and relatively unaffected by magnetic pull. Scientists believe that viewing the sun's polar environment will simplify studies of how particles travel away from the sun.

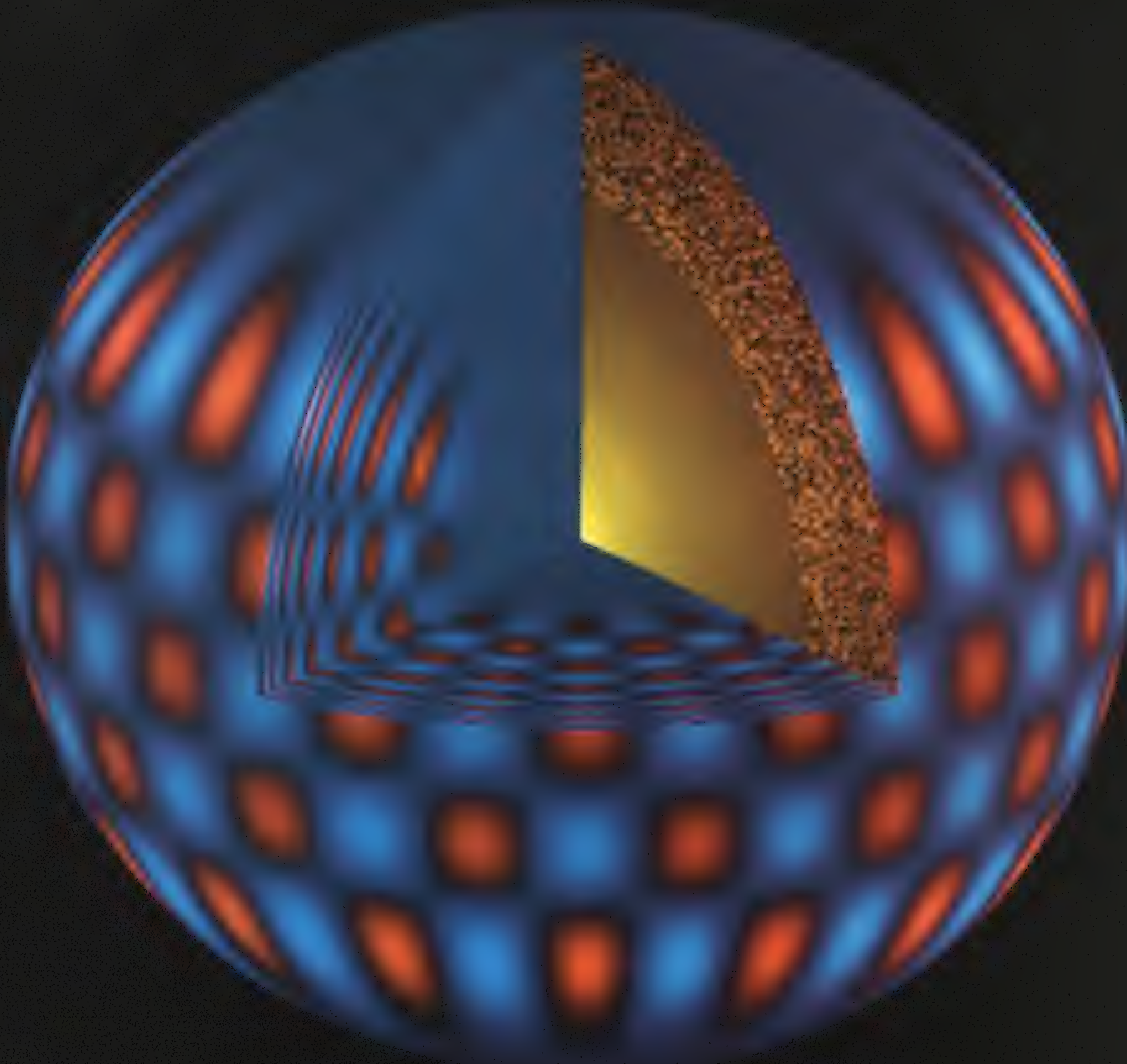
They also hope that *Ulysses* will intercept some cosmic rays, atomic particles moving *toward* the sun from interstellar space. Cosmic rays are thought to be pieces of atoms accelerated to near-light speeds by supernovas—explosions of massive stars within our galaxy. (In their most potent form, the rays possess more energy than any cyclotron, or "atom smasher," can crank out on Earth.) The particles are coded

with precious information about their presumably violent origins, but when cosmic rays enter the ecliptic plane, their scientific messages are scrambled by the sun's magnetic field. "We don't know what cosmic rays are like out in interstellar space because we have never sampled them," Smith says. If all goes well, *Ulysses* will record some of these cosmic messengers before they are altered by solar magnetic forces.

Meanwhile, as *Ulysses* awaits a chance to get into space, a spacecraft called the *Solar Maximum Mission* (*Solar Max*) is keeping an eye on the sun. *Solar Max* has been sending back data for more than six years, and some of the information hints that the sun's output of radiation is declining. "It looks as if the sun's average output has dropped by about one tenth of one percent," says Richard Willson, principal investigator for *Solar Max* at NASA's Jet Propulsion Laboratory, in Pasadena, California. The dimming might be due to permanent changes in the sun's internal workings, or it could be connected to the solar magnetic cycle, with the sun brightening and dimming as magnetic activity peaks and wanes.

With the 84-inch McMath solar telescope scientists are trying to fathom the turbulent interior of the sun (above).

For reasons not yet known, the dynamo that produces the sun's magnetic field changes radically at regular intervals. Every 22 years, the sun's magnetic poles do a 180-degree flip, so that a compass placed on the sun pointing north during one cycle would point in the opposite direction 22 years later. Fitting neatly within this cycle of magnetic flipping are 11-year cycles of magnetic activity, which, at their peak, are associated with large numbers of sunspots and solar flares that erupt from the sun's surface. The last cyclical peak occurred in 1980 when *Solar Max* was launched, hence its name. *Solar Max* continues to make observations during the present solar minimum, and scientists are waiting to see if the dimming will stop with the next peak in magnetic activity, expected about five years from now. "That's something we will be eager to find out as solar activity starts to pick up," Willson says.



If the solar constant (the steady output of the sun) is on a permanent decline, the effects will be dramatic. According to accepted models of Earth's climate, a one percent change in the solar constant would alter the average global temperature by one to two degrees Celsius, or roughly two to four degrees Fahrenheit. "We could be headed for disaster," says Jack Eddy. "The Little Ice Age that occurred between about 1550 and 1850 was a cooling of about one degree Celsius in global average temperature, and that was enough to cause a lot of hardship in Europe." The last major ice age, which ended 10,000 to 15,000 years ago and covered most of the northern United States in glacial ice, resulted from a five to ten degree Celsius drop in average global surface temperature.

That cooling was not caused by an internal change in the sun, however, but by a periodic shifting of the Earth's orbit and the tilt of its axis of rotation. Even if the sun's output remains constant, observations of how the Earth wobbles on its axis and shifts its orbit all point to another major ice age within the next several thousand years. The combined one-two punch of a major ice age due to the Earth's subtle shifting and a drop in the sun's luminosity could spell real trouble. A ten percent decrease in sunlight reaching Earth could trigger irreversible runaway glaciation and an ice-covered planet. On the other hand, a drop in global temperature might be a blessing in disguise, counteracting the "greenhouse effect" that may be brewing because of an increase in carbon dioxide in the atmosphere largely from widespread burning of fossil fuels. "If the sun's output really is falling, it might be the greatest gift that nature could give us because it will counterbalance the almost certain rise in temperature from carbon-dioxide buildup," Eddy says.

Solar Max also carries a device called a coronagraph, which is helping refine our knowledge of the sun's tenuous outer layer. About one hundred billionth as bright as the sun's main disk, the corona is difficult to study from Earth—astronomers can catch only fleeting glimpses during solar eclipses, when the moon blocks light from the main disk. But spacecraft equipped with a coronagraph, a telescope outfitted with an opaque shield that produces an artificial eclipse, can deliver much better images. Indeed, eclipses now are more cause for excitement among Earthbound amateur astronomers than among professionals.

In the early 1970s, long-term coronagraph observations made from *Skylab* revealed that the sun's corona violently ejects about ten billion tons of matter every one to two days. These solar hiccups, called coronal mass ejections, account for as much as ten percent of the particles in the solar wind. "The geomagnetic effects of this material as it hurtles out and strikes the Earth's magnetic field are not understood," says Robert M. MacQueen, director of the High Altitude Observatory in Boulder, Colorado. The forces that accelerate the ejected material to a speed of a million miles per hour also remain a mystery. "It appears in most cases not to be a localized nuclear-bomb-type effect, because we see these great aggregates of material accelerated outward over enormous distances, five and six times the diameter of the sun, which means the force is acting over millions of miles," he explains. The secret of this phenomenon, too, may well lie in changes in the sun's magnetic field.

Solar oscillations show up as red (ebb) and blue (flow) in this image produced by the Global Observing Network.

Paul Chesley

Solar pioneer Jack Eddy (left) suspected the sun was shrinking, but Timothy Brown—and his telescope—said no.

Surface magnetic fields, acting as windows into the sun's inner workings, are presently being mapped in three dimensions—a tremendously difficult undertaking. To observe the configuration of magnetic fields, astronomers use a technique called Stokes polarimetry, which interprets light emitted by particles moving along the sun's magnetic field lines. (The light from such a particle reveals its orientation relative to the magnetic field.) Astronomers have found that field lines tend to congregate in tremendously powerful clumps, sometimes only a few hundred miles wide, barely large enough to be observed by Earth telescopes. An improved polarimeter that will be able to map these clumped field lines in detail is now being developed at the High Altitude Observatory.

Another exciting new field of solar research is called helioseismology. About a decade ago, scientists learned that the sun oscillates in subtle motions that have been compared to the quivering of a water droplet or the ringing of a bell. Just as geologists send seismic waves deep into the Earth to measure its interior, solar physicists plan to divine the nature of the sun's interior by analyzing these oscillations.

Oscillating waves on the sun's surface reach heights of only a few meters, rising and falling as slowly as a third of an inch per second. The miniscule movements toward or away from Earth are measured by observing the Doppler shifting of light: as the sun's surface moves toward the observer, waves of light are shifted toward the blue end of the spectrum; as the surface retreats, the sun's light shifts toward the red. Scientists know that oscillations of certain frequencies stay close to the sun's surface while others travel through the core. "So if we can measure these oscillations accurately enough, we can get an idea of what it's like—how hot, how dense—at the center of

Jet Propulsion Laboratory

In the 1990s a "Starprobe" spacecraft may nose-dive through the sun's atmosphere for the closest look ever at Old Sol.

the sun," says William Livingston, an astronomer for the National Solar Observatory in Sunspot, New Mexico.

Livingston uses the 84-inch McMath telescope on Kitt Peak in Arizona, the largest solar telescope in the world, to monitor solar oscillations. To complement telescopic observations, Timothy Brown of the High Altitude Observatory and John Evans of the National Solar Observatory have designed a device called a Fourier tachometer that measures and analyzes oscillations over the entire surface of the sun. Their preliminary results indicate that, while the sun's outer surface rotates at differing speeds depending on latitude, the interior rotates much like a solid ball.

Exactly how the oscillations originate is not yet clear, but excited solar astronomers are organizing an aggressive program, aptly named GONG, for Global Observing Network Group, to conduct an international around-the-clock study by telescope of the sun's "ringing." Of course, the sun never sets in interplanetary space, and instruments to measure solar oscillations will be aboard another American-European project, SOHO-Cluster, a small fleet of spacecraft that may be launched in the 1990s. Orbiting at a gravitationally stable point between the sun and Earth, SOHO (Solar and Heliospheric Observatory) will correlate its observations with a group of four sister spacecraft known as Cluster.

But the big question that has arisen only recently is whether the sun is shrinking. In 1979, after examining records from England's Greenwich Observatory, solar physicist Jack Eddy decided that it was. From the days of wooden sailing ships until 1953 when the observatory shut down, a telescope at Greenwich noted the passage of the sun directly overhead to establish high noon. An observer would note when the sun was centered in the telescope's view finder and signal for a large ball to be dropped at the observatory to inform ships in the harbor that it was noon on the dot. Navigators depended upon a sextant and chronometer to plot their positions, so knowing the correct time was the key to accurate navigation. In the mid-nineteenth century, astronomer George Airy installed a new telescope so precise that Greenwich eventually was designated as the official zero meridian of longitude for the rest of the world. ("The French wanted badly to have Paris defined as the prime meridian," Eddy says. But the Americans, who had defined zero longitude as the telescope at the U.S. Naval Observatory in Washington, D.C., sided with Britain.) Eddy consulted solar records from Airy's telescope and concluded, startlingly, that the sun's diameter had been shrinking by about five feet per hour.

Other scientists thought Eddy was off base. One of the skeptics was Irwin Shapiro, now director of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, who looked up similar records for the planet Mercury and found evidence to dispute Eddy's finding. By looking at times when Mercury crossed the edges of the sun, Shapiro determined that even if the sun were shrinking, the rate was less than a tenth of what Eddy predicted. "I think that was one of the first well-placed shots at my Greenwich finding," says Eddy. Still, the question remained open as other studies both confirmed and refuted the theory. A great deal hinged on the outcome of the controversy, because a changing solar diameter would have important implications for theories about the stability of the sun and how solar energy is generated.

"Given that situation," MacQueen says, "we built a special instrument at the High Altitude Observatory four and a half years ago to measure the diameter of the sun precisely and on a daily basis." According to Timothy Brown, who's conducting the solar-diameter study, the data have been processed recently and show no change in the diameter of the sun greater than about 30 feet per day. And given the instrument's possible margin of error, the change recorded "is indistinguishable from zero," Brown says. Case closed.

Looking toward the twenty-first century, solar research could become even more adventurous. Mission planners at the Jet Propulsion Laboratory are nurturing an embryonic project known as *Starprobe*, a spacecraft that could fly through the sun's upper atmosphere and even sample its forbidding fire. Tucked safely behind a 450-pound conical shield made of composite material that would progressively burn away to dissipate the heat, *Starprobe*'s telescopes would peek through a tiny hole in the cone to view our star 15 times more closely than any previous spacecraft, and its plasma detectors would attempt to pick up particles thrown off the sun. If funds materialize, *Starprobe* might fly as early as the late 1990s. But for now, solar scientists have plenty of puzzles to solve until *Ulysses* and its successors reveal new mysteries worth investigating—as, most scientists agree, they surely will.

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Baja Whale Watch February 23-March 3 or March 3-11: Explore beauty of Baja California in company of gentle gray whales.

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Big Bend April 14-23: Hike the spectacular canyon trails in this southwestern Texas wilderness park.

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National Air and Space Weekend May 1-3: Explore the past, present and future of air and space travel through special tours and lectures at NASM and its outreach facilities.

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Getting there is more than half the fun when you fly on a DC-3.

By Patricia Trenner

Callers to most airlines are concerned with finding the least circuitous route to their destination at the lowest price. However, many callers to Provincetown-Boston Airline (PBA) alter their priorities, in conversations such as this:

"Good morning, PBA reservations."

"Hi. I hear you still fly DC-3s. How can I get on one?"

"What is your departure city and

Carol Lee

your destination?"

"It doesn't matter. I just want to fly somewhere on a DC-3."

"Well, let me give you a list of short flights with the lowest fares."

"I don't care how much it costs. Just get me on one."

These folks often value nostalgia over practicality and age over beauty, too, by asking for a seat on "Old 36," the airplane that breaks a record every time it

Something Special in the Air

Passengers don't need airstairs and baggage carousels—sneakers and strong arms suffice.

flies. Built nearly 50 years ago, Old 36 has spent more time in the air than any other aircraft known today. It has logged more than 89,300 hours of flight time, the equivalent of putting, oh, about nine million miles on your car.

People of all ages are enchanted by the charismatic DC-3. Some flew on them as children, when hot meals were first served in flight: fried chicken, mashed potatoes with gravy, and peas were standard fare. Some were on board during World War II, when they hauled everything from toilet paper to generals. Some know them only from history books and family scrapbooks.

To all admirers, there is something just plain lovable about the looks of the airplane. People are drawn to it as to a large, playful dog. And indeed, the DC-3 has the personality of an aging golden retriever: not tremendously bright, but fiercely loyal and anxious to please. It is perhaps even more endearing on the ground than in the air, with its plump fuselage crouching on the ramp, snub nose high, broad tail low, wings canted upward, impatient to fly.

Carol Lee

Carol Lee

An open cockpit window is an armrest for Captain Dave Rice—aloft as well as on the ground on sunny days (top). Carry-on luggage isn't limited to briefcases and overnight bags—and there's no surcharge for canines (above). Quick aircraft turnarounds at Hyannis keep PBA crews and operations staff hopping (right).

No other airplane revolutionized air travel as did the DC-3, designed and built by the Douglas Aircraft Company from 1935 to 1946. Its passenger capacity, fuel efficiency, and low maintenance costs meant the airlines could finally turn a profit flying passengers rather than mail. Some 800 were sold as airliners, and more than 10,000 were built for the military, most designated as C-47s and C-53s and nicknamed "Gooneybirds." The DC-3's strength and load-carrying ability surpassed all competitors: to this day, none has ever suffered a structural failure.

As testimony to its dogged reliability, more than 1,500 still fly today. Some spray against mosquitoes, some haul cargo, and some carry passengers for regional airlines such as PBA, now a subsidiary of People Express.

PBA maintains ten 30-seat DC-3s, the largest DC-3 passenger fleet in the country, along with three other aircraft types of more recent vintage. Late in 1984, when the Federal Aviation Administration temporarily shut down operations at PBA after finding serious gaps in mandatory pilot training for some of the contemporary transports, a

cloud of bad press swirled around the company but left the DC-3 fleet and its squeaky-clean record unsullied.

The DC-3s fly New England routes in the summer, catering to Cape Cod vacationers, and southern Florida routes in the winter, primarily between Miami and Key West. The fleet migrates back and forth from its home base in Hyannis, Massachusetts. PBA founder John Van Arsdale bought his first DC-3 in 1968, but unlike his nostalgic passengers, has no romantic attachments to his classics: "I bought them because I could make more money with them than with anything else," he says. The company paid $50,000 or less per aircraft and refurbished each for another $150,000. A contemporary replacement like the Embraer EMB-120 Brasilia turboprop commuter runs about $5.5 million and carries the same number of passengers in far less comfort.

Of course, today's transports are much faster than a DC-3, but because most PBA trips last less than an hour, speed is not of the essence. Besides, at 150 mph and 3,000 feet, "If you fly over a football field, you have time to see a play," says PBA captain Tony Freitas.

Old 36—"our pride and joy," according to Freitas—was built in October 1937, and is now registered as N136PB. It is not PBA's oldest airplane: N43PB left the Douglas factory in July of the same year. But no other aircraft flew so fast and furious as 36PB, which had ten owners prior to PBA, including the War Department in the early 1940s. Five years ago, Old 36 surpassed the previous flight-time record, held by a North Central Airlines DC-3 built in 1939, which retired in 1975 to the Henry Ford Museum in Dearborn, Michigan, with 84,875 hours of service. "There's no reason for us to retire our DC-3s," Freitas says, "unless we run out of spare parts. And they are getting scarce these days."

Brian Smith

It's the scarcity of engine parts that concerns Basler Flight Service of Oshkosh, Wisconsin, one of the largest refurbishers of DC-3s. "There were so many DC-3s built that spare parts for the airframe may never be a problem," says company president Warren Basler. "The sad part is the engines. It's cost-prohibitive to replace all the cylinders,

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so we're replacing the piston engines with turboprops. It makes for a $2 million aircraft, but that's still a lot cheaper than a new turboprop transport."

It's a typically sunny day in Key West as Old 36 arrives from Miami. There, the sight of a DC-3 proudly taxiing around its mammoth DC-10 descendants draws the curious to the terminal windows, but here, its arrival draws only a baggage cart, barefoot passengers, and a change of crew. Captain Dave Rice and First Officer James Pitts will fly Old 36 for the afternoon shift.

Old 36 grinds over Key West during the afternoon shift of flights to Miami and back (above). Cockpit instruments have been updated over the years, but the most useful piece of equipment is still the windshield (left).

Rice, 31, has logged "too many" hours—over 3,500—in DC-3s, and instructs new PBA pilots in the aircraft's eccentricities. The DC-3 has a huge vertical tail that is influenced by the slightest breeze, and because all airplanes—particularly those with a tailwheel like the DC-3—want to turn into the wind like a giant weather vane, controlling the airplane at slow speeds and on gusty days takes the skill of a jockey maneuvering a skittish thoroughbred. "It'll wrap you up in a ball in a crosswind," says Rice. Such terse statements do not mask his fondness for the airplane as well as he might wish.

"It's not an airplane for the timid pilot," adds Pitts, 31, who has logged 500 hours of DC-3 time. "You have to be aggressive. Even with no wind, landings can give you a headache. But pilots without experience in a tailwheel airplane like this are really lacking basic aerodynamics—seat-of-the-pants flying—in their training."

Rice and Pitts complete their preflight walk-around inspection of the airplane, make the steep climb up the passenger aisle to the cockpit, and settle into their seats as if into well-worn Barcaloungers. A passenger asks if the old radial engines are cooperative in starting. "Sometimes you have to do a little drum roll, but usually they start right up," Rice says, coaxing the right engine, which coughs, catches, and belches a great cloud of smoke from the oil that accumulates in the cylinders when the engines are shut down. The last Pratt & Whitney round engines were built in 1951; PBA overhauls its DC-3 engines every 1,500 hours.

The takeoff check list is done with hand signals, as is almost all cockpit communicating once the engines are at cruise power. Their song is best described as a pair of 1,400-pound Cuisinarts trying to purée a set of china. The crew wears ear protectors, but with both side windows open over the Gulf of Mexico on a warm afternoon, the din is deafening. High-time DC-3 pilots seem to say "What?" frequently.

Cockpit amenities are sparse: no headsets with built-in microphones, no air conditioning, no autopilot. Hand-held mikes are used to talk to air traffic controllers, who can identify the aircraft type by the engine racket that precedes every voice transmission.

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Preventative maintenance between flights contributes to the DC-3's remarkable longevity (left).

The Pratt & Whitney radial engines are as reliable—and as smoky at start-up—as they were 50 years ago (right).

Most PBA pilots are about 20 years younger than the DC-3s they fly. "WHEN I BEGAN FLYING THESE, MY FIRST THOUGHT WAS, 'HOW MANY PEOPLE HAVE SAT HERE BEFORE ME?' " Pitts shouts. "MY FATHER FLEW C-47S DURING THE WAR, AND RIGHT OFF HE ASKED ME, 'DO THEY STILL LEAK AROUND THE WINDSHIELD WHEN IT RAINS?' " They do. "THEY'RE NOT MUCH FUN TO FLY ON RAINY DAYS," adds Rice.

Back in the passenger cabin, where the engine noise is tolerable, a father tells his son, "I used to jump out of these during the war." Flight attendant Debbie Rhoades is equally down-to-earth: "This airplane is like my old Volkswagen: cheap, dependable transportation—with a few idiosyncracies."

"We get a lot of people from Europe, especially England, who go out of their way to fly on these airplanes," says Rice. "We once had a Concorde captain who was so thrilled to be on board that he promised us two seats in trade on the SST." So far, they haven't taken him up on the offer. Two former passengers were even more taken with the romance of the aircraft—they held their weddings on board.

Before landing at Miami airport, the sign-language check list is performed, the hydraulic landing-gear lever is lowered and latched, and as a final gear check, Rice and Pitts each stick their head out a window for a look at the fat tires, down and locked. Passengers put their shoes on, and a couple of DC-9s wait impatiently on the taxiway for takeoff clearance as Old 36 slows to 100

Brian

mph or so, floats over the runway numbers, and is reined to a docile landing by Pitts. PBA's DC-3s roost outside a small terminal, where the airplane gets a 15-minute rest while Miami passengers get off and Key West passengers take their place.

The southwest-bound trip frames the late afternoon sun in the windshield, and the crew arranges PBA flight schedules on the windshield as visors. At 4,500 feet, 36PB is a time machine grinding over a landscape sufficiently hazy to erase four decades of development; it could be en route to Casablanca to pick up Ingrid Bergman as she leaves Humphrey Bogart on the runway.

Fifty minutes later the airplane is on the ground, scurrying around an Eastern 727 and heading for the terminal. The Eastern captain pauses in the walk-around inspection of his jetliner to gaze reverently at Old 36 as it completes another record flight, upholding the noble tradition of the airplane that opened up the sky for an entire generation.

Brian Smith

Brian Smith

First Officer James Pitts, left, and Captain Jan Ketelsen, both younger than the DC-3s they fly, relax briefly at Miami International (left).

Off on another routine but record flight, Old 36 adds more flight time to its whopping total of more than 89,300 hours in the air (above).

By Benjamin Lawless

The $457 Astronaut

Astrochimp, Chimponaut, or First Mercury Astronaut—whatever you call him, HAM had the right stuff, and he proved it to the world.

Photographs courtesy NASA

He was small, standing just an inch or two over three feet tall and weighing only 37 pounds. But though dwarfed by the other Mercury astronauts, he proved big enough to blaze a trail for the rest of them down the Atlantic Missile Range. Indeed, his pioneering journey opened the door for U.S. manned space flight.

He was called Chang when the Air Force bought him for $457 in 1959. And when sent for training to the Holloman Aeromedical Research Laboratories near Alamogordo, New Mexico, he was dubbed Number 65. While this utilitarian moniker distinguished him from his fellow space trainees, it was hardly a fitting name for the first "pilot" of a Mercury capsule launched into space by a Redstone rocket. Thus, just hours before liftoff on the morning of January 31, 1961, Number 65's trainers decided that an acronym derived from Holloman AeroMedical would be a good name for their jug-eared space traveler. And so, when the countdown ended at Cape Canaveral and Mercury-Redstone 2 thundered into the sky, it was "HAM" who entered history books.

Moments after liftoff things began to go wrong. The Redstone rocket burned fuel faster than planned and reached a top speed of more than 5,000 mph instead of the projected 4,000 mph. The extra thrust pushed the Mercury capsule to a record-breaking altitude of 155 miles rather than the intended

Mercury-Redstone 2 is readied for its headline-making passenger, a chimpanzee called HAM (above).

Though much went wrong on his 5,000-mph ride into space, HAM performed almost flawlessly (left).

HAM's health, both physiological and psychological, was monitored before, during, and after his flight (below).

Airborne again in his Mercury capsule, HAM is taken to the U.S.S. Donner *for medical evaluation (above).*

115 miles, and the capsule splashed into the Atlantic 420 miles downrange rather than 290 miles. Fifteen minutes after liftoff, Navy ships patrolling the planned splashdown zone were looking for the capsule's parachute—but Mercury 2 and HAM were still 40 miles overhead and falling toward the horizon at better than 90 miles a minute. That wasn't all: when the capsule finally splashed down, it tipped over onto its side. And because the pressurized bulkhead had been punctured in several places sometime during the wild ride, the capsule slowly took on water. HAM's mission was not going very well.

Indeed, the entire U.S. space program was in trouble. In November of the previous year, the first Mercury-Redstone had risen just inches from the launch pad when its engines shut down. (In December, a second launch attempt was successful.) This followed hard on the heels of problems with putting satellites into orbit: of the 18 Vanguard and Explorer satellites that the United States attempted to orbit in 1958 and 1959, 11 failed. The press had taken to calling American space attempts "Kaputnik." About all that the National Aeronautics and Space Administration had going for it on that last day of January in 1961 was a skinny little simian in a shiny plastic space suit flying higher, faster, and farther than any other member of the Mercury-Redstone astronaut program.

Almost three hours later a Marine helicopter pulled HAM's leaking capsule from the water and flew it to the deck of the U.S.S. *Donner.* Doctors, scientists, and technicians crowded around as HAM's tiny contoured couch was removed. Minutes later a hot little chimpanzee was having his pulse taken while quietly observing the excitement around him.

HAM was just four years old when he was drafted by the Air Force and enrolled in the Restraint Conditioning of Large Biological Specimens program, a jawbreaking title for a scientific study to determine whether animals could live and work in space. Sputnik, orbited by the Soviet Union in 1957, had proved that manmade objects could withstand the vacuum, extreme temperatures, and radiation of space. But questions still remained about the ability of humans to travel in space: could the body survive the gravitational forces of liftoff and landing? Could the brain function in the absence of gravity? Would the disorientation caused by weightlessness prevent astronauts from operating their spacecraft? Would there be long-lasting psychological or physiological effects?

Both the Americans and the Soviets sent animals on flights in early space capsules to get preliminary answers to such questions. The Soviets used dogs—Laika, Strelka, and Belka—while the Americans sent aloft mice, rhesus monkeys, and chimpanzees. While the smaller animals could prove only that living creatures could go into space, perform basic bodily

functions in weightlessness, and come back alive, chimpanzees could be trained to perform specific tasks, and their performance during and after space flight could be compared to their previous abilities.

HAM was blissfully unaware of these concerns as he began his training. He seemed to enjoy the attention from the hosts of veterinarians, doctors, biologists, pathologists, and mechanical and electrical engineers who worked with Holloman's 16 would-be space voyagers during the critical first phase of their training. HAM followed a rigorous schedule that began at 7:30 a.m. with a light breakfast of "monkey pellets" (dried cereal), grapefruit, and a cup of gelatin. After a physical examination, HAM was dressed in his "space suit," a lightweight nylon coverall. Then he and his companions rode a bus to the Comparative Psychology Branch Training Center, a brightly lighted, temperature-controlled building in which the student chimps were introduced to a variety of learning tasks.

Each "chimponaut," as the trainers often called their furry charges, was fitted to a contoured plastic couch similar to those designed for the human Mercury astronauts to provide support and protection during space flight. Nylon harnesses fastened to the chimps' space suits kept the hyperactive young trainees in check as they were tested for their ability to withstand the physical rigors of space. They were strapped into centrifuges and spun around, to get a foretaste of the forces encountered during liftoff. They rode rocket-powered sleds that reached speeds up to hundreds of miles an hour and then stopped within seconds, to get accustomed to deceleration. They were put in high-altitude chambers, hot chambers, cold chambers, and isolation chambers. In fact, their routine was virtually identical to what the human astronauts experienced.

Early in their training all the prospective astrochimps were introduced to the Response Testing Machine. The device was simple enough: three colored lights and two small levers mounted on a small control panel. When a light flashed on, the chimp was to perform a specified task—press a particular lever once, or 50 times, or wait five seconds and then press the lever. If the chimp executed a sequence of commands correctly, he earned a banana pellet or a drink of water. If he made a mistake, he received an electric shock. A computer monitored the chimps' responses and made the programs more difficult as the trainees' skills improved. Even so, the chimps became remarkably adept at working the machines: once, a chimp slipped out of his harness and ran through the entire program with his feet. Another chimp pushed levers on cue 7,000 times, making only 20 mistakes. This accomplishment so impressed a visiting congressman that he tried the machine himself, only to flunk badly. But since the monkey-pellet reward and hotfoot punishment were missing from the legislator's program, he may not have really been trying.

In phase two of their training program, the chimps had to operate the Response Testing Machine under conditions approximating those of space. Technicians at Holloman reproduced the Mercury capsule down to the last detail, and engine vibrations and other sights and sounds were even piped in during the tests.

After 18 months of training, four of the chimps had washed out, either by failing tests or by growing too much—chimps had to weigh less than 50 pounds to be eligible for space flight.

HAM didn't win a space ride on brains—there were smarter chimps—but on coordination and personality.

HAM wasn't the smartest of the 12 Holloman graduates, but he was the most coordinated and most resistant to motion sickness, disorientation, and loneliness. The human Mercury astronauts were selected on similar grounds.

In early January of 1961, HAM and five classmates—four females and one other male—were flown to Cape Canaveral. There they waited until the scheduled launch date. Just 24 hours before liftoff, Number 65 and one alternate (whose identity is lost to history) were selected for the mission on the basis of their overall psychological and physiological health, as well as the results of a final preflight check-out with that old standby, the Response Testing Machine.

HAM completed his historic space mission with flying colors, consistently pulling the correct levers during his six minutes of weightlessness. His success demonstrated once and for all that the Mercury capsule's life-support system worked just fine: HAM's heart rate, respiratory rate, and body temperature were monitored closely throughout the flight and all remained within acceptable ranges.

The next morning, HAM's freckled face adorned the front page of newspapers across the country, and he was soon on the cover of *Life* magazine. The public's enthusiasm over HAM's flight caught the attention of the newly inaugurated John F. Kennedy, who began to take a closer look at the nation's space program. Three and a half months later, Alan Shepard—who styled himself "the link between HAM and man"—completed

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a sub-orbital flight using the Mercury-Redstone system that HAM had "flight-tested." Weeks later, on May 25, 1961, President Kennedy committed the United States to landing a man on the moon before the end of the decade.

HAM, meanwhile, was back at Holloman, working the Response Testing Machine and submitting to tests to reassure the scientists—not to mention the human astronauts—that he had suffered no ill effects from his epochal journey. The perks now associated with being a space hero—a presidential phone call after splashdown, ticker-tape parades, airline executive positions, seats in Congress—eluded HAM. His best offer came from the Smithsonian's National Zoological Park in Washington, D.C., where director Theodore Reed recognized a good animal exhibit when he saw one. The Air Force transferred the little astronaut to the zoo in 1963.

HAM's stay, however, didn't prove especially happy. At first, visitors jostled one another for a peek at the original Mercury astronaut, but his celebrity status proved short-lived. And HAM's recreational opportunities were limited: aside from a convivial hour or two a week sharing a stick of chewing gum with his keepers, HAM spent most of his time eating, sleeping, or swinging on the parallel bars in his solitary cage. He was a trained spaceman in an animal's skin, thought by his keepers to be too "human" to fraternize with others of his kind and too much of an ape to be allowed close contact with people.

"We might have made a wrong assumption about old HAM," Melanie Bond, one of HAM's keepers, reflects. "Maybe chimps and other trained animals are not as messed up as we think they are." Miles Roberts, a research mammalogist at the zoo, also recalls the chimp fondly. "HAM let it all

Deborah Fronsdahl

The memorial plaque at the International Space Hall of Fame in Alamogordo, New Mexico, concludes, "HAM proved that mankind could live and work in space" (above).

At age 23, HAM (on left) had more than earned his pastoral retirement at the North Carolina Zoological Park.

hang out," he says. "There wasn't a deceitful bone in his body. Every keeper has three or four animals that really stick in his memory, and HAM was one of my all-time favorites."

This personal relationship prompted Roberts to look around for a new home for his chimp friend. He found just the spot at the North Carolina Zoological Park in Asheboro. Although the zoo wasn't in the business of retraining space chimps, general curator Les Schobert felt that HAM could be returned to a healthy mental condition through association with other chimpanzees. "He displayed a lot of aberrant behavior when we got him in 1980," Schobert remembers. "But people are sometimes too quick to dismiss animals that aren't behaving normally; they often can be trained to live a natural life."

Schobert was right. HAM was carefully introduced to a community of seven other chimpanzees. Four months into the resocialization program, conducted out of the public's eye, HAM had paired with a young female named Maggie and was starting to relate to the other chimps. Then, on a warm December afternoon in 1980, the gates to the outdoor exhibit area opened and Maggie led HAM into the sunshine. The old astronaut blinked and then moved slowly to a large rock at the center of the park. There he settled himself and gazed quite contentedly at the others of his troop scampering and whooping among the trees and bushes.

On January 17, 1983, HAM was discovered slumped against the doorway of the chimp house. He had died of heart and liver disease, common conditions among large captive primates. His remains were flown to Alamogordo, New Mexico, and buried outside the International Space Hall of Fame. It is a fitting resting place, indeed.

The Man Who Would Be Right

A scientist from Down Under is shaking up the cosmic community. Is he correct? The *Voyager* spacecraft's next stop may tell.

By Anthony Liversidge


Anthony Liversidge

Andrew Prentice is trying to tell the world how the solar system began, but the world isn't really listening.

"Those boys are waiting for the biggest thunderclap they've ever heard. It'll stretch all the way up to the Yukon!" Andrew Prentice's blue eyes blaze gleefully as he anticipates the impact of new data from deep space on the U.S. scientific establishment in his particular field. He is a cosmogonist, a man who has built a theory of the way the solar system began.

The time is last March. The place is Prentice's small office at Monash University, just outside Melbourne, Australia. On the walls are photographs and diagrams of planets and their moons. In a corner is the computer on which the 42-year-old mathematician runs his models of the solar system. This room is headquarters for his one-man battle to convince the scientists who dominate cosmogony that they are wrong and he, like Galileo, is right.

Only weeks earlier, on January 24, the *Voyager 2* spacecraft swept past Uranus, taking the first close look at the blue-green, methane-laden planet and its strangely scarred moons. Radioed 1.8 billion miles back to Earth, the probe's measurements matched several of Prentice's bold predictions.

But if Prentice expected his life's work to be officially vindicated, he is still awaiting his laurel wreath. Like an elephant brushing off a gadfly, the Astrophysical Establishment has seemed more irritated than interested. Its members dismiss Prentice's ideas as "simplistic," "mere numerology," and "physically impossible."

The way Prentice sees it, the planetary in-crowd is closing ranks against an outsider: "In no way does the U.S. camp want to give me any credit at all for what I have achieved." His detractors insist that it is merely a matter of reputable scientists saving precious time by ignoring doubtful ideas.

One thing the dispute usefully underscores is the fact, surprising to many, that the origin of Earth and our solar system is still one of the great unanswered questions.

Prentice's uphill battle began at Oxford University in England, where he

studied cosmogony in the 1960s under Dirk ter Haar, a respected Dutch theoretical physicist. Ter Haar advised him to tackle the age-old puzzle of how the sun and its satellites were born, 4.6 billion years ago. Theories abounded, but Prentice wasn't happy with them. So, modifying one of ter Haar's ideas, Prentice breathed new life into the old "nebula hypothesis" of the Marquis Pierre Simon de Laplace. In 1796 this brilliant French astronomer suggested that a vast, whirling cloud (or nebula) of gas threw off a series of rings, which turned into the planets and their moons.

Laplace proposed that as the cloud contracted under the force of gravity, it began to rotate faster, just as a figure skater might do by pulling in her arms. And as the spin increased, so did the centrifugal force at the cloud's equator. When this outward force exceeded the pull of gravity, a ring of gas was thrown off, slowing the cloud's core for a while. Repetition produced a series of rings, each of which condensed into a spinning planet. By the same process, each planet also threw off moons.

This concept explains a puzzle that has long intrigued astronomers: why each planet (save Pluto, the farthest out) is roughly twice the distance from the sun as its inner neighbor. The rings also suggest why the planets travel around the sun in the same direction and in roughly the same plane, and why they rotate the same way as the sun.

Laplace's proposal fell out of favor in the 1860s, when French scientists pointed to an apparent flaw. The planets don't have enough mass to account for how much material had to have been lost by the sun as it contracted and threw off rings. Also, the theory couldn't fully explain why the collapsing cloud would shed a number of separate rings, rather than a continuous disk.

Prentice answered these objections by calling upon an unconfirmed phenomenon called supersonic turbulence. Many theorists suppose that there was intense turbulence in the gases of the early sun, but that the gases jostled about at subsonic speeds. Prentice, however, envisaged needle-like jets of gas shooting from the core of the protosun to its surface at velocities up to ten times the speed of sound, then falling back into the interior. Prentice claimed it was this high-speed turbulence that made the cloud throw off a series of rings rather than a disk.

Adding supersonic turbulence to his model gave results that agreed with the positions and the masses of the planets. His vision, he argued, also agreed with observations of so-called T-Tauri stars, thought to be young suns in the process of forming planetary systems.

But most physicists objected, maintaining that his supersonic gas jets were physically impossible. They claimed that laboratory experiments, as well as experience with aircraft and hydrogen bomb explosions, show that supersonic motions in gases cannot last more than an instant, because the shock waves generated quickly turn the energy of movement into heat.

Prentice's scientific papers were rejected time after time by *Nature, Science,* and other top British and U.S. journals. ("The underlying theory is nonsense," groused one scientist serving as a "referee" for papers submitted to *Nature.*) His work eventually found a home in reputable but less prominent publications, such as *Astronomy and Astrophysics* and *The Australian Physicist.* In one case, the editors even overruled their academic advisors.

When the National Aeronautics and Space Administration (NASA) launched *Voyager 1* and *Voyager 2* nine years ago, Prentice saw his chance. He would use his model to predict what the twin space probes would find as they swept past Jupiter, Saturn, Uranus, and Neptune. As his mentor Dirk ter Haar noted, "When experts disagree violently, there is no substitute for observational tests of predictions."

Prentice made various predictions about the locations and chemical compositions of the planets and their moons. The strategy seemed to pay off when a number of the early discoveries made by *Voyager 1* matched Prentice's forecasts. The spacecraft found a rocky ring around Jupiter. Saturn's moons were less dense the farther they were from the planet. The density of Tethys, one of Saturn's moons, turned out to be 21.4 percent higher than measurements made from Earth had indicated: Prentice's prediction that it would be 20 to 25 percent denser had been scorned.

However, other predictions, such as that Saturn's moons might be egg-shaped, didn't prove out. And most planetary scientists remained unconvinced by the Prentice-Laplacian model.

So it was the *Voyager 2* flyby of Uranus in January that Prentice hoped would finally, dramatically, bear out his ideas. He went out on the proverbial limb for the occasion, predicting not only the makeup of the planet's known moons, but also where the spacecraft would find five unseen moons.

It was a time of tension and high drama. In fact, among the places he outlined his predictions was a meeting of the American Astronomical Society in Houston. Just before he began his talk, he heard on the radio that *Voyager* on its approach to Uranus had indeed discovered a new moon, but its location was not reported. Rushing to the newsstand after he had finished, Prentice was relieved to find that the moon's orbit was 53,370 miles out from the planet, close to the 55,302 miles that he had predicted.

When more results came in, it looked like Bingo! Four other moons were detected close to the orbital positions Prentice had predicted. The outermost moon was only one tenth the size he expected, however. And when ten new moons eventually turned up, his predictions looked much less impressive. Prentice suggested that six of the ten might be pieces of one original moon, since their orbits averaged out at one moon position he predicted at 42,250 miles. But with so many new moons, as Ellis Miner, deputy chief scientist on the *Voyager* team, commented, "You could almost choose any theory and find a match to it."

Prentice did well in his predictions about the physical makeup of the moons. He put the average density of the five known moons at 1.35 grams per cubic centimeter, very close to the 1.37 actually measured. A leading U.S. expert on planetary formation, David Stevenson, a New Zealander now at the California Institute of Technology, had only predicted the "spread": that the average density would fall between 1 and 1.9 grams per cubic centimeter. Stevenson insists that Prentice's bull's eye was pure luck. "It's sheer foolishness to make any predictions when there are so many ways you can affect

the densities," he says. Other scientists note that while Prentice may have hit the *average* density for the five moons, his predictions for individual moons were farther from the mark.

To Prentice, however, the discoveries added up to "extremely powerful confirmation of the theory." And there have been a few small signs of professional recognition. The Radio Science Team at CalTech's Jet Propulsion Laboratory (JPL), headquarters for the flyby mission, has included Prentice as a co-author on at least one of its papers. However, his name and a description of his modeling work were deleted "for space reasons" from a summary article in *Science*, though he was credited in a footnote. The editor of *Nature* has also invited him to write a paper on what he now calls Prentice's "rather nice theory on the origin of the planets."

Most U.S. scientists, however, remain as cold as Uranian moons to his ideas. At most, they grant that it is "interesting that Prentice was able to do that well" on satellite positions, as theorist John Lewis of the University of Arizona puts it. Opponents jump on the fact that Prentice's original estimates of the density of the Uranian moons were, in fact, wide of the mark. He hastily revised them, they recall, when he arrived at JPL and was warned that his figures looked awry, in light of preliminary data gathered from *Voyager* while on its approach to Uranus.

Prentice freely admits that he was tipped off early, re-examined his model, and decided that an estimate by another physicist of the amount of methane in the atmosphere of Uranus was the culprit. "If I try to run my model with a wrong measurement given to me, of course I am going to be wrong," he says. Prentice ran his model with correct data and sent his revised calculations to *Physics Letters*, a Dutch journal, still two days in advance of the flyby.

Critics also chip away at his earlier achievements. "The 'rocky ring' around Jupiter is a complete misnomer," says Stanley Dermott, an astrophysicist at Cornell University. "There is just a very small amount of debris, hardly anything there at all." And the perceived decline in the densities of the moons of Saturn outward from the planet may disappear in a revision of data by JPL's Radio Science Team, which may also wipe out the roughly 21 percent increase in the mass of Tethys that Prentice is credited with predicting. Yet the debate will continue, because even those figures will not be final: the Radio Science Team didn't get a direct reading on every moon, so the estimates are indirect calculations.

Many of the engineering scientists for the *Voyager* mission, who are more concerned with gathering experimental data than with theory, remain fairly impressed with the performance of the Prentice-Laplacian model. "If I were in his shoes, I'd toot my horn a little bit," says Von R. Eshleman, a professor of electrical engineering at Stanford University. "His theory is definitely viable, experimentally," says mission team member John Anderson. "I'm not saying it is right, but it passed all tests in that nothing in the *Voyager* data completely contradicted it." The JPL team has invited Prentice back in 1989, when *Voyager 2* will encounter Neptune.

Prentice hopes the giant Space Telescope, when finally in orbit, will find evidence supporting his theory by monitoring young suns in the throes of forming planets. Even then, he says "those boys will pretend no one ever thought of it before."

If Prentice is wrong, how do critics account for his many apparent successes in predicting moon locations and densities in unexplored planetary systems? One answer is that it's easy to pick and choose among the data. "The danger in this field is that you can find support for your point of view if you look around, no matter what it is," says David Black, chief scientist in charge of NASA's proposed space station.

But whether Prentice's numerical predictions survive or not doesn't seem to matter to many of the theorists because, as one says, when it comes to supersonic turbulence, they "gag." Prentice is still backed by Dirk ter Haar, however, who points out that determining whether supersonic turbulence is right or wrong is more a matter for a hydrodynamicist, a specialist in fluid mechanics, to decide.

One such expert, Edward Spiegel of Columbia University's astronomy department, is supportive. He believes that supersonic turbulence played a role in the formation of the solar system, although, he says, "Andrew's vision of of it is not mine." Prentice's theory of turbulence is not worked out in sufficient detail to justify outright rejection, Spiegel says. "Neither of us has a mathematical theory worth mentioning. Nor does anyone else."

Both friend and foe agree that Prentice must fully explain how supersonic turbulence could work, or abandon it for some other mechanism that will give the same results. But the idea is a vital pillar of his model, Prentice insists, and he isn't interested in hunting for a substitute. "If another theorist can demonstrate that my formula emerges from some other physics, then I won't be so egocentric as to insist on supersonic turbulence," he says. "But find me a man with a mechanism!"

One comfort is that none of his theoretical tormentors is doing any better. With a mass of new data from the *Voyager* spacecraft and ground-based observations, and the increasing use of supercomputers to test ideas, cosmogony is active. But as A.G. Cameron, a well-known astrophysicist and theorist at Harvard University, says, "To the extent that there are competing models these days, they are all wrong and we are struggling to come up with some better calculations to replace them. What is clear is that the rather simplistic assumptions we have all been making up to now are quite inadequate."

But Prentice hasn't given up the fight, and he is looking forward to the *Voyager 2* encounter with Neptune in 1989 for further confirmation of his ideas. Though the Neptune system is evidently not a miniature solar system in pattern, he will predict the locations of possible new moons and the densities of Neptune's two known satellites.

He hopes, too, that the giant Hubble Space Telescope to be launched by the shuttle when it's back in action will find clearer evidence of supersonic turbulence in young T-Tauri stars. But even if it does, Andrew Prentice expects that "those boys will pretend no one ever thought of the idea before."

Ancient Aerodynamics

John Gurche

Over countless years, birds evolved from prehistoric reptiles. Now, debate swirls over how the first bird learned to fly.

The local aerial acrobats make their last passes of the day—perhaps their last of the season. These fliers are chimney swifts and they are scheduled to leave soon for the upper Amazon. Tonight they swoop in tight formation over the porch and soar vertically up and over the roof. Any minute now their place will be taken by a handful of bats, frantic ghosts in the dusk.

The bats are good fliers, don't get me wrong, but by comparison the swifts are the real thing. They should be: birds have been flying a lot longer.

The changeover to the night shift focuses attention on the idea of the air as a place to make a living, an "ecological niche," in the coin of the scientific realm. It seems straightforward enough—especially to someone so at home on the ground as I am—that a long time ago some fish hauled themselves out of the sea and tentatively took up life on land. This is a reasonable, plodding sort of development. But for a land animal to take to the *air*. . . what a radical thing to do.

We've done it, of course. During a startlingly brief interval of time (even if you look as far back as Daedalus), engineers answered our urge and gave us proper engines and wings—bingo—just like that. But biological evolution doesn't make such quantum leaps: a pair of lizards simply doesn't all of a sudden spawn a bird.

Yet paleontologists, whose ecological niche includes knowing about such matters, say that birds did indeed arise—literally and figuratively—from reptiles. There had to be lots of incremental steps along the way—but in the relatively stately pace of bird evolution, most of the steps are lost to history. There are comparatively few fossil remains of birds and fewer yet of their reptilian ancestors, or "pre-birds."

The brightest gem in the sparsely jeweled tiara of bird paleontology is called *Archaeopteryx*. It was a creature with a reptilian bone structure adorned with feathers in all the right places, including the tail. It dates back 140 million years to the beginning of the Jurassic Age, when dinosaurs and other charismatic reptiles were beginning to take over.

However, paleontologists at Texas Tech University have recently turned up fossil remains of a new candidate for the first bird—dated 75 million years earlier than *Archaeopteryx*. This crow-sized creature

had long legs and a tail like a running reptile, but wing-like forelegs, a skull much like a bird's, and a breastbone that could have supported muscles used in flight. It also had hollow bones, an avian trait. And while the fossil lacked clear impressions of feathers, microscopic examination of the forelegs revealed tiny bumps to which feathers could have been attached.

With Texan confidence, Sankar Chatterjee and his colleagues named their discovery *Protoavis*, which means ancestral bird. Other scientists are intrigued, but not all are convinced. "It looks bird," says Smithsonian paleontologist Nicholas Hotton, while John Ostrom of Yale University, an authority on *Archaeopteryx*, says there isn't enough evidence to support the claim of feathers.

But even if the Texans are right that *Protoavis* is the true goods and that *Archaeopteryx* was only a dead-end offshoot (like Neanderthal Man in the human evolutionary tree), the path from reptile to bird nonetheless remains a mystery that has challenged paleontologists for more than a century since the remains of *Archaeopteryx* were found in Bavaria. Lately some aerodynamicists with a bit of spare time on their hands have joined the discussion. Both groups are satisfied that *Archaeopteryx* could fly, however clumsily. What they argue about is how its reptilian ancestors became "pre-adapted" to flight. Remember, here, that each adaptation an animal makes usually must confer a *current* advantage in a *current* environment.

The most popular view among scientists had been that pre-birds began as tree-climbing animals that developed the capacity to glide, using forelegs that had become primitive airfoils. Like flying squirrels, they would start from the treetops, glide to the ground to forage, climb another tree, glide down—extending their foraging range with a minimum of energy. Rudimentary flapping, increasing the foraging area yet further, would soon lead to fully powered, horizontal flight—bird flight. This is dubbed the arboreal, or trees-down, hypothesis.

On the other hand, it also seems possible that a pre-bird might have become a bipedal, or two-legged, runner (as did many reptiles) that gradually developed wing-like forelegs to give the animal a bit of lift, more speed at less energy, and maneuverability as it chased insect prey. The process of natural selection would inexorably favor stronger and stronger pectoral muscles, and the creature would take to flapping its wings as it ran—like a goose—one day finding itself flying. This possibility, called the cursorial, or ground-up, hypothesis, is advocated by a team of researchers at Northern Arizona University.

What's more, the Arizonans say, the competition's entry faces serious aerodynamic problems. Although its wing-like forelegs might be okay for gliding, they wouldn't be much good for real flying. A flapping wing, it turns out, gets most of its thrust from the outer one-third of its length—but the arboreal glider's stubby wings wouldn't have had much of an outer one-third, as it were. A "powered wing" needs more span to flap effectively—something more bird-like—and the Arizonans can't see the incremental steps of evolutionary change bridging this gap. In other words, a glider that began flapping its wings would be wasting a lot of energy—like a parrot with clipped wings—and would soon lose the evolutionary race.

Not necessarily so, says Ulla Norberg of the University of Göteborg in Sweden. She and her team have subjected the mathematical equivalent of *Archaeopteryx* to rigorous modeling via computer and found out how fast that once and future bird had to flap its wings to extend its gliding range to a helpful degree. About six flaps per second would do it . . . but that, Norberg then found, was what a bird of the same size does today, and presumably no neophyte flapper could have achieved that rate.

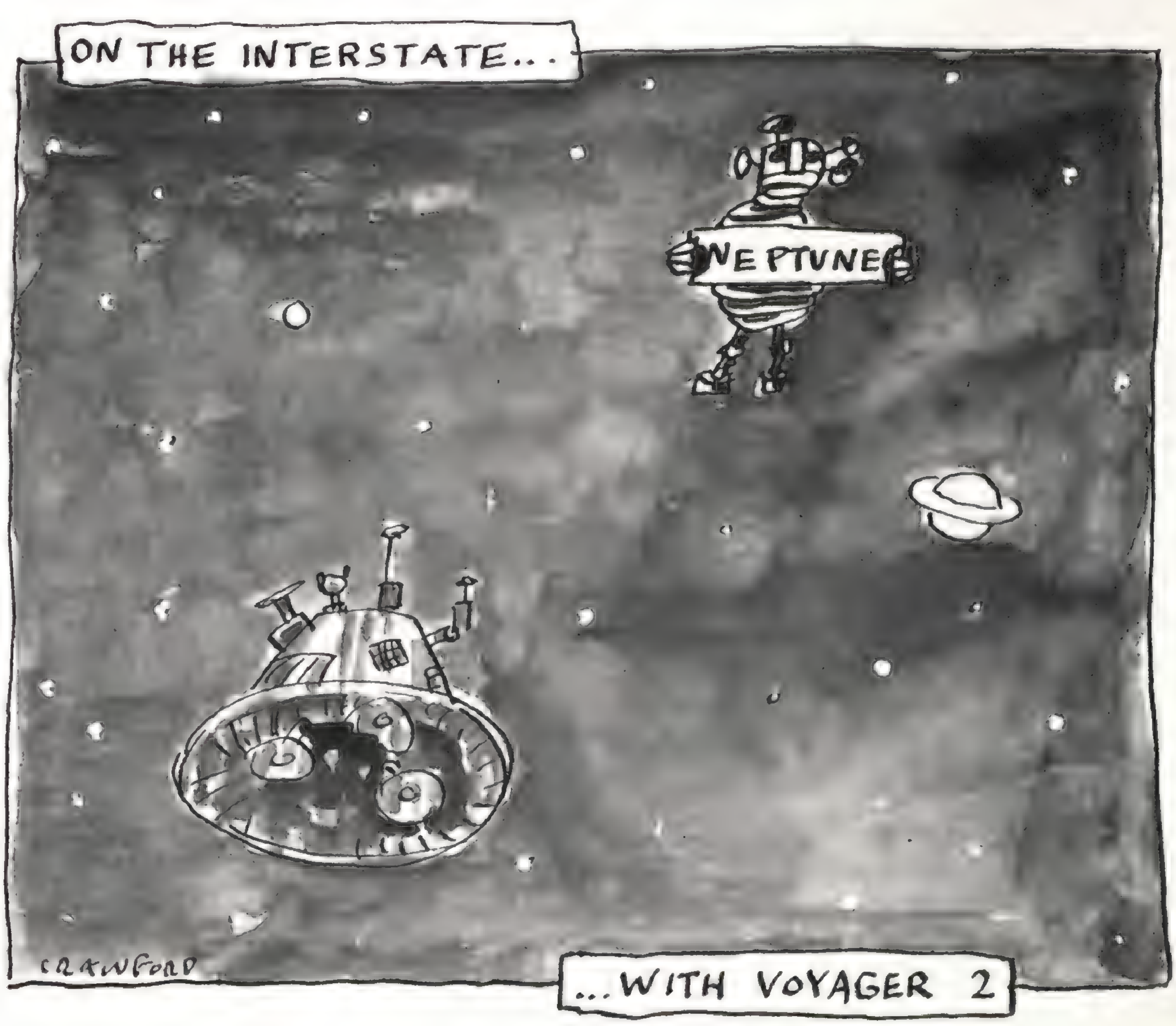
Still, there is an intermediate kind of flight between gliding and flapping, and Norberg believes that this is what *Archaeopteryx* probably used. By flapping its wings down fast and then bringing them up slowly, the bird would get all the thrust and lift needed with a mere two wing beats a second. This "flap-gliding," she claims, is theoretically akin to a long glide down and then a quick climb, a highly efficient way to use energy while foraging from tree to tree that is used by many birds today. The undulating flight of a goldfinch, for example, is up to 20 percent cheaper in fuel cost than full-bore horizontal flight.

But, the Arizonans counter, modern birds don't use the fast-down/slow-up wing beat, not even those species that glide and climb in undulating flight. If flap-gliding is so efficient, why isn't it used now? Furthermore, their calculations for the lift and thrust of such a wing beat come out differently than Norberg's. So the question remains up in the air—where it belongs.

I'm delighted that the aerodynamicists are getting into this act. Mathematical models are terrific and they may get us closer to an answer. Math always adds zest to a game. And the nice thing about this kind of paleontological game is that it's never really over. We'll never know for certain how reptiles came to be birds: it will remain a natural wonder.

Meanwhile, the bats are now flittering overhead and some pest of an insect has bitten me several times. I wonder how *they* got into the flying business . . .

—Jake Page



A Cosmonaut's Odyssey

On May 13, 1982, cosmonauts Valentin Lebedev and Anatoly Berezovoy lifted off in a Soyuz T spacecraft for the Soviet Union's brand-new space station, Salyut 7. *The veteran Lebedev, who became a cosmonaut in 1972 at the age of 30, had made his first foray into space in December 1973 as flight engineer aboard the space capsule* Soyuz 13. *That mission lasted eight days. When he and Berezovoy returned to Earth in December 1982 from* Salyut, *they had set a record by staying in space for 211 days.*

Lebedev struggled on and off with frustration, fatigue, and loneliness during his seven-month stay on Salyut, *which saw visits from two other cosmonaut crews and a tiring trip outside the space station for a repair job. Soviet citizens learned of Lebedev's psychological odyssey when, on August 13, 1983, the Soviet newspaper* Pravda *published excerpts from a diary that the cosmonaut wrote in every day of his 211 aloft.*

Now known as "Twice Hero of the Soviet Union, Pilot-Cosmonaut of the U.S.S.R.," Lebedev graduated from the Moscow Aviation Institute in 1966 with an engineering degree; he is married to a fellow engineer, Lyudmila.

After training five years, Valentin Lebedev finally got to work in open space.

SOVFOTO

April 28. I have come so far for my second mission. . . and tomorrow I fly to Baikonur [the space launch center].

[Ten-year-old] Vitaliy caressed me and kissed me; he sensed, dear boy, that his father was flying off for a long time.

April 29. A fine morning. Only in my soul is there something unquiet. We worked at the assembly and test building on the transport vehicle. I was surprised at the calm.

May 11. I took a stroll before sleeping and thought of the work and the long years leading to my second flight. Now I had reached the summit, and I was frightened—not from the dangers that are possible in our profession, not from the difficulties of a long mission and the great amount of work, but of myself.

May 12. I talked frankly with Tolya [Anatoly Berezovoy]. We swore an oath: in any situation we would be temperate, good-willed, and try to maintain good relations.

May 13: Launch Day. Liftoff. We jerked left and right as though we would lose our balance; we hung for two or three seconds, and then, like breaking a chain, we were off.

May 14. I awoke at two o'clock in the morning. Tolya was sleeping in the living section. I swam about, looking for him, but he was not there; there were only the two pressure suits hanging on the hooks. What kind of witchcraft was this? In the dark, I touched the pressure suit on the divan; Tolya was inside. He had climbed inside the suit because he was cold. I did not wake him but sat writing in my diary.

The thing that surprises me most of all here is that there is no sense of the unusual; I do not go into ecstasies about the Earth. It is as if I fly regularly. At every free moment Tolya looks out through the port: "Val, look!" And I answer: "O.K., we'll have half a year to look at it."

Now comes the docking [with *Salyut*].

We've docked. When I went into the station the first thing that surprised me was that I did not recognize it.

May 16. I got up at 0800 hours with the left side of my head aching. Tolya was talking in his sleep. Feelings throughout the day come in waves: in the morning you are a little dull; after breakfast things are better.

June 18. Today Tolya and I looked at an island near Cape Horn covered with snow against the background of the blue ocean and the trails of various kinds of clouds. It was very beautiful.

Each evening they transmit to us the latest news. As we fly calmly above the Earth we listen to Radio Moscow.

Above my bed there hangs a photograph of little Vitaliy, and there is a package of photographs: Lyusya [Lyudmila] and myself, my father, and friends. Each evening I kiss the photograph of my son. He looks out at me so kindly that when things are difficult I say to him, "It's nothing, son, I'll manage. Papa will not let you down."

Life here is all bustle, like in the countryside. From morning until night we swarm about at our business, just like doing the main fieldwork.

June 20. During physical training, a footstrap broke and today we had to sew it back on. The thread behaves in a very interesting way in zero gravity. It is not so easy to thread it into the needle when it has no weight. It gets tangled, so I held one end in my teeth and tried to put the other end in the needle. It worked.

We have eaten all the soups (they went down very well). Now we are eating buckwheat porridge, candies, and canned goods; the bread is almost gone. The "Frenchies" [the first visiting crew, which included a Frenchman] will have nothing to eat, we think; they had better bring their own food.

June 24. We are now no longer alone in space; we have comrades with us. They are in orbit below us, but tomorrow they will come up for the docking.

June 25. We are expecting our guests. Tolya and I have already settled down in our relationship, and now there are new people. We two have become used to each other, worked things out, and now it looks as if we have to start again.

The hatches opened; we met, embraced. Everything was all right. Sasha and Volodya [visiting cosmonauts Aleksandr Ivanchenkov and Vladimir Dzanibekov] felt fine. Their mood was excellent.

Everyone went to sleep, but I went into another section to read. Lyusya and little

Vitaliy had written me many letters. Then I lay down to sleep, but I could not close my eyes for thinking about the letters and what we would say when we met, and the great deal of work coming up with the guests.

June 26. Jean [Chrétien, a French "spacionaut"], the clown, had brought a Quasimodo mask, and when I was working, he put it on. I was lying behind a panel when a dishevelled gargoyle shuffled in from the scientific apparatus section, and I gave a loud shriek. Everyone laughed. Later Jean stood the mask on an equipment platform, and I photographed it.

We entrusted Jean with the honorable task of dumping the domestic garbage through the hatchway. We launch these "sputniks" every day.

June 28. We worked all day. The boys from the visiting expedition looked at the Earth for a long time. Sasha Ivanchenkov showed us the places that remind him most of his first flight. As Jean and I looked at the Earth through the ports, he said, "How beautiful and incomprehensible it all is. Why these kinds of clouds, and where are they going? There are many mysteries."

July 1. We sleep only three or four hours during these days when the visiting expedition is aboard. Jean flies between us to watch us working. He complains to Earth that there are too many television reports, not enough time to look at the Earth.

An impression of how we work in the dark: five men are all at their instruments. Lamps twinkle on the panels, flares from the engines come in through the ports, the station rumbles as they burn. It's really quite fantastic.

July 2. Volodya started to gather things up for the reentry—cassettes with movies and still film, results from biological experiments, and so forth.

We sat together for supper, and Volodya said some fine things about friendship. Jean said that he was impressed by the high professional skills of each of us.

After supper, we started to cancel the envelopes with the station franks and write letters. Volodya trimmed Tolya's hair.

We went to the hatchway to see the boys off. And then our hearts ached. Volodya and Jean had tears in their eyes. We embraced and kissed, and on command from Earth our hatch started slowly to close. Then we heard the boys closing the hatch of their own vehicle.

I went to take a photograph of the vehicle as it left us. It turned gently and then moved out of the view from the port, and I lost sight of it. And so we parted.

July 9. A little about our everyday life. We wash, if you can call it that, by sponging ourselves with wet tissues that are stored in polyethylene packs. We clean our teeth with our fingers wrapped in tissues. We shave with a regular shaver that has a chamber for collecting the whiskers.

The most essential instruments aboard are knives. Each of us has them secured with a cord to the pocket, and we need them every minute, to prepare food, do repair work—everything starts with opening a package or cutting strings.

July 14. We did a television report in the afternoon, and then we congratulated Tolina's [Berezovoy's] daughter Tanya on her eighth birthday. We made a cake from packets of bread. Instead of candles we used felt-tipped pens, and we simulated the tongues of flame with foil. There were also electric candles—four flash lamps, and to make eight, for her age, we used the reflection from a mirror. We hung various colored balloons and scooted about on the vacuum cleaner and a ball.

July 16. The mission is becoming increasingly difficult. Against the background of increasing tiredness, blunders in communication with Earth lie in wait. There are tense moments, but no outburst can be permitted. Visual observations are calming.

July 26. Now the main task is to make a space walk successfully.

July 27. As I started to don the pressure suit, I felt as if the shoulders were too large and the head would not fit. I got into the suit lying down, and I had to use my arms to get my legs in. Groaning and thumping about, I slid right in and stood up.

Then Tolya donned a suit. We began to check the seals; in 30 seconds, the pressure dropped four points. No good. We repeated the check, but the problem remained. It turned out that a strap from the water-cooled suit had fallen into the wrong place. We checked again: everything was normal.

July 28. We overslept. They woke us from Earth for the final day of preparation for the space walk.

I recalled my first flight on the *Soyuz 13.* Then I had a great desire to go out into open space and sprawl there above the Earth. Finally I was going to fulfill my dream. After nine years! Five of them were in direct training, with hundreds of exhausting hours on the simulators, in pressure chambers, in aircraft, under water, in class, with dozens and dozens of examinations. The agitation, the sweat to get to this moment! And now I cannot believe that the day of the space walk is approaching. It was worth all the years of hard study for this.

July 29. I got no sleep at all, thinking about home, the mission, friends, work. I really needed to sleep, at least a bit, but I could not, and so I obtained satisfaction and even pleasure from just thinking.

July 31. Well, it is all behind now. The space walk is over. It lasted two hours

and 38 minutes.

After opening the exit hatch, I turned the handle of the lock, and immediately a chink of bright white light from the sun appeared. I opened the hatch, and it was like being in a light snow on a frosty day—dust from the station was floating around in the form of tiny sparklets. Like a gigantic vacuum cleaner, space began to draw everything outside. Along with the dust, tiny washers and nuts that had somehow been lost flew out of the station; a pencil floated by.

I had no fear or worry at all. My first feeling on opening the hatch was of a huge Earth and a sense of the unreality of everything that was happening. Space is very beautiful, and you sense the Earth's roundness much more strongly than through the station port. All around there is perfect silence, with no feeling of the speed of the flight. No wind whistles in your ears, nothing weighs you down. The panorama is calm, majestic. The silence is striking. The station is frozen in space. There is no sensation even of vibration, even though hundreds of instruments and dozens of fans are operating inside.

August 20. Today we were waiting for the boys from *Soyuz T-7.* We saw the transport vehicle from a distance of five kilometers, moving like a great star, illuminated by the low sun. Next to it was a real star. All very beautiful.

August 21. [Visiting cosmonaut] Svetlana Savitskaya spent a long time in the transport vehicle getting herself ready.

In the afternoon, we were busy with medical matters. Lenya [Leonid Popov] and Sveta [Savitskaya] worked cheerfully.

Now they are sleeping as I write. I look at them. Lenya is facing me, and Sveta's arm has come out of her sleeping bag and is just hanging there.

August 24. The days pass quickly, even though there is much work. Now I shall write a letter; it is already midnight and I am tired, but I must. Where are my darlings? They probably think about me.

August 26. Today is the final day of the visiting expedition's stay. The main feeling before they leave is not even the slightest concern that they are returning to Earth while we remain behind. Only two months from now I will be able to think and hope about our landing.

September 6. I sang songs and flew about the station. Will I really sometime be on Earth among my own people?

I have started to sleep badly. I dream about different things, and I remember home. Before sleeping, it is pleasant to read a newspaper that I have already read a dozen times.

September 10. The first shoots have appeared in our vegetable garden; peas and wheat. Peas grow in a very interesting way: they come out of the soil already robust, with a thick stalk and leaves, and they are densely packed. Wheat just goes straight up, like a green ray of light. It is pleasant to touch the shoots with the palm of the hand—they tickle.

October 21. We await the decision of the state commission: will the mission be continued or not?

We have prepared a radio message for the state commission: "A month and a half ago it was suggested that work be prolonged aboard the station. We earnestly request that you take into account our desire, attitude, and readiness to carry out an additional work program."

December 7. A busy day. I slept badly; Tolya did not sleep at all. There was much work. We clambered around every nook and cranny in the station, and we wrote up the status on board: no damage to the hull, no rust or moisture. Using the vacuum cleaner behind the panels, we made many little "discoveries," domestic articles and instrument parts lost at some time that we sucked out from behind the panels.

The landing will be soon.

December 9. A mood I do not understand: worry. How are things down there? Our life has been adapted to a small little island in space, and then suddenly, the Big World! I am not myself. Go to sleep! Tomorrow we return home, to Earth.

December 10. We cannot believe we are going home. Everything is over, no more journeying! We are home. I see the Earth in the port, pink in the clouds lit by the low sun, with a blue light on the edge of the bright, sunset horizon. Beautiful.

Reprinted courtesy of Pravda.

Lebedev returned to Earth by parachute; future cosmonauts may use a shuttle.

Pioneering the Space Frontier: The Report of the National Commission on Space. *By the National Commission on Space. Bantam Books, 1986. 213 pp., color illustrations, $14.95 (paperback).*

From time to time, yet another panel brings forth yet another report on the condition and prospects of the U.S. space program. Most of these studies have little influence and quickly sink out of sight. This does not seem the likely fate of the report of the National Commission on Space.

Certainly, *Pioneering the Space Frontier* is much more attractively packaged than most of its predecessors. Bantam Books has put together a handsome volume featuring the works of accomplished space artists including Chesley Bonestell, William Hartmann, and Robert McCall. The commission's report also comes at an opportune time, in the confused aftermath of the loss of *Challenger*. And while most of the text predates the catastrophe, the report could not have been better shaped to pierce the cloud of our mourning and trepidation.

But prettiness and timeliness alone would not make this study influential. There must also be substance. Chairman (and former National Aeronautics and Space Administration administrator) Thomas O. Paine and his fellow commissioners offer a challenge, and a clarity of vision, showing that leadership has not vanished after all. The dream is still alive.

While acknowledging today's tight budgetary climate, the commissioners nevertheless propose a truly vigorous national—and international—space program that would encourage fundamental scientific research in space, open space to vigorous commerce, and create opportunities for a true "frontier" in space, where people would explore, work and live.

The report describes possible paths into space, including a large "Earthport" space station, a return to the moon, industrial facilities in lunar orbit, and research settlements on Mars and Phobos. These are stirring goals. But they are also goals which have been formulated before, to little avail.

The difference this time lies in an attitude of economic, political, and engineering practicality, and something else—a willingness to depart daringly from past dogmas.

The commission does not call for a return to Apollo-like funding levels. Probably nothing short of another *Sputnik*-style surprise could alter the nation's priorities that much. Instead, Paine's committee believes we should invest a constant and predictable one tenth of one percent of the U.S. gross national product in a well-organized and worthwhile space program.

Permeating the report is implicit criticism of the space shuttle program, with its emphasis on just one type of re-usable vehicle to carry both bulk cargo and human beings. Even before the *Challenger* calamity, the commissioners agreed that we must differentiate between a low-cost, high-volume capability for launching replaceable goods and a deliberate, focused approach to manned spaceflight.

And yet, the commission cautions against leaping too quickly to adopt replacements for the shuttle, urging instead that NASA triple the amount spent on developing basic space transportation technologies. "We have been living off the capital of the Apollo years," they write.

The commissioners argue that we must pursue fundamental investigations before deciding on the right transportation systems. Among the promising technologies are "scramjets" for air-breathing, single-stage-to-orbit vehicles. Orbital transfer vehicles will be vital, and a necessary technology for their success will be "aerobraking"—using a planet's atmosphere to divert or slow a hurtling spacecraft into a desired trajectory.

The promise of tethers that could link objects in space is at last acknowledged. Some believe tethers will be the greatest advance in space transport since the invention of multi-staged rockets, and the commissioners agree that the potential merits extensive experimentation. They also ask for one more look at finding uses for the space shuttle's external tanks in orbit. NASA's pre-*Challenger* ten-year plan called for discarding 10,000 tons of tankage into the ocean, mass which comes within

Pioneering the Space Frontier *includes plans for a 21st-century lunar settlement.*

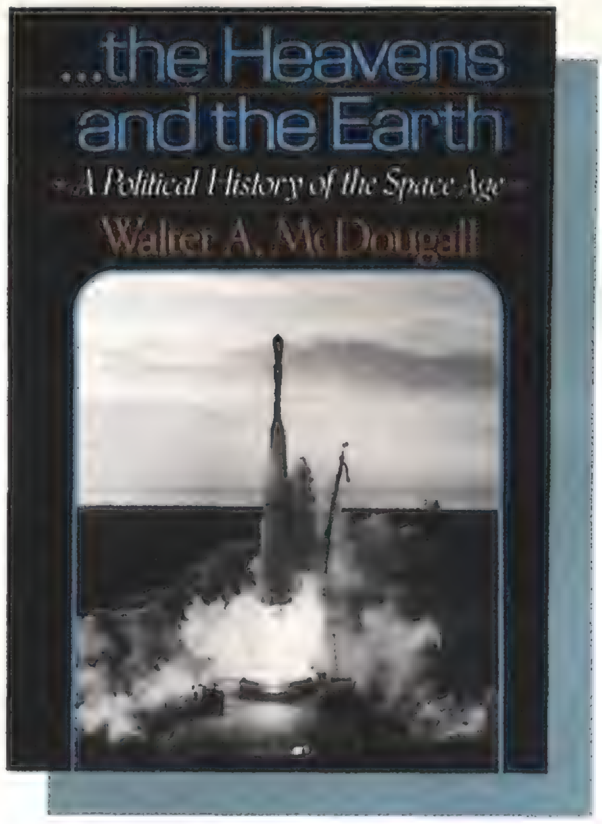
Robert McCall

one percent of orbital velocity. At standard rates it would cost $35 billion to lift that much mass to such energies. Surely some use could be found for these great potential resources up in orbit.

Most important, the commission recommends bringing a new spirit of bold management and vision to America's space effort, and it makes practical proposals to that end.

How can we open the space frontier for the benefit of all humanity? Clearly our allies, our competitors, government, businesss, and the public are all part of the answer. *Pioneering the Space Frontier* is an audacious, beautiful, and thought-provoking sketch of how these pieces might fit together, and the dream of the future set in motion once again.

—Dr. David Brin writes both fiction and non-fiction books about space exploration. He has been an Associate at the California Space Institute in San Diego.



. . . the Heavens and the Earth: A Political History of the Space Age. *By Walter A. McDougall. Basic Books, Inc., 1985. 555 pp., b&w illus., $25.95 (hardbound).*

Everything about Project Apollo, the U.S. program to land men on the moon, was big, bold, and monumental, seemingly as vast as space itself. Moreover, it worked. The *Apollo 11* astronauts touched down on the lunar surface on July 20, 1969, within the deadline of the decade that John F. Kennedy had set in 1961. The accomplishment reignited the American "can do" spirit, left the upstart Russians far behind in the great 1960s space race, and helped insulate national pride against the enveloping tragedy of Vietnam and the collective traumas of assassinations and urban revolt.

There was even some down-to-earth pork barrel to pass around. On May 23, 1961, just two days before Kennedy's message to Congress staking out the manned landings as a national goal, NASA administrator James Webb wrote a memo to Lyndon B. Johnson, Texan, vice president, and the Kennedy administration's chief space booster. A federally created research installation in the Dallas-Houston area, Webb wrote, "would provide a great impetus to the intellectual and industrial base of this whole region." In addition, other centers could be built in California, Chicago, the Northeast, and the Southeast, "perhaps revolving round the research triangle in North Carolina (in which Charlie Jones as the ranking minority member on [George] Thomas' Appropriations Subcommittee would have an interest). . . . "

In short, there was something for everyone in the great American tradition.

Walter McDougall's *. . . the Heavens and the Earth* touches on all these aspects of Apollo. But McDougall's lengthy work—no fewer than 461 pages of text plus almost 100 pages of notes and charts—explores none of them adequately. His coverage is like one of those occasional freak snowstorms that fall on Dallas-Houston—a mile wide, an inch deep, and soon evaporated.

This is all the more deplorable because a political history of space developments since 1957's *Sputnik I* is long overdue. We need someone to pull together all the elements that went into the great U.S.-Soviet competition of the 1950s and 1960s and the rather surprising post-lunar landing play out of that race. For all practical purposes McDougall's narrative does little more than connect up the events of 1957 to 1969, and winds down with the conclusion of the Apollo program. Space in the 1970s and 1980s—Soviet plans for permanently manned space stations, what the Reagan Administration may be up to—gets less than a page.

Even if one accepts McDougall as a historian of the *Sputnik*-to-Apollo period, his effort has little predictive value; neither his narrative nor his lessons can be used as guides to present activities, much less to future developments. Nothing in his 500-plus pages, for example, prepares us for the particular trajectory of the shuttle program. Yet McDougall finds time and space for some pretentious mumblings about The Meaning Of It All, and whether technology can lead us to something outside ourselves, to G.O.D. (his arch spelling), a Guarantor of Destiny. Quoting everybody from Tolstoy (Leo) to Dylan (Bob), McDougall sounds like a George Will gone wild.

Authors, of course, should be reviewed for the books they write, not the ones they don't. McDougall is encyclopedic all right, and he has done his share of scholarly research. But his judgments are suspect. The German contribution to rocketry is tidied up considerably. The escape of Wernher von Braun, et al., to the West at the end of the war reads like a whiz-bang boy's adventure. The legacy these dashing rocketeers left behind warrants only a sentence or two, albeit powerful ones. ("Nearby [the Americans] found the workers' camp and thousands of corpses stacked here and there as garbage awaiting pickup. If too weak to work, slaves were left to expire—150 per day—human sacrifices on the altar of machines and power . . . .") The Soviets, meanwhile, are consistently baited and bashed. Was their effort all lies, trickery, gulags, and peasant gruntings, or could there have been one or two decent Soviet scientists or non-robotic cosmonauts?

Most disturbing of all, though, is the murkiness of McDougall's central thesis. There can be no going back on technology, he says, no counterrevolution as there can be in politics, no return to the *ancien régime* of 1941 or 1957. Okay, so far. The reader can even stay with McDougall for the next phase of his erratic ride, and grant that the unending race to keep up with foreign military and economic competition can threaten freedom and other fundamental Western values. But McDougall is apparently unable to come up with any examples of space technology crushing individual freedoms. The most he can offer is that space-race fever created not so much a technocracy of the technicians—as Eisenhower predicted in his warnings about the emergence of a military-industrial-scientific complex—but a "technocracy of the politicians, arrogating to government the right to fix a national agenda and order fabrication of techniques, both hardware and management, for its fulfillment."

But hey, McDougall! The last time I looked, representative democracy *was* one of our Western values, and a cherished one at that. Reading McDougall and looking out at our present Washington regime of non-technocratic, non-politicians running away from governance, I must confess (though I never dreamed this day would come): I miss Webb, Johnson, the Apollo Project (pork barrel and all) and the whole Western, liberal humanist idea of an activist government that believes it can set ambitious national goals, and carry them out.

—Edwin Diamond covered the early days of the Apollo program for Newsweek. *He is now director of the News Study Group at New York University.*

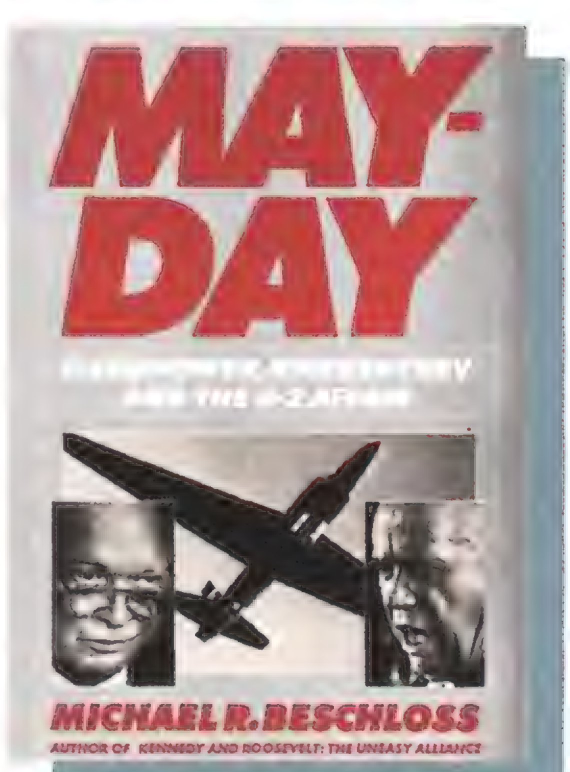
Mayday: Eisenhower, Khrushchev and the U-2 Affair. *By Michael R. Beschloss. Harper & Row, 1986. 494 pp., b&w photos, $19.95 (hardbound).*

Mayday tells the story of the U-2 incident, an event that marked the end of innocence for millions of Americans. I will never forget the combination of anger and disbelief I felt that Saturday night in 1960 as my colleagues and I gathered around the wire service printer at a small newspaper in Oklahoma and read that the United States had admitted to spying on the Soviet Union.

With all the wisdom of my 20 years, I knew that we didn't spy and we didn't lie. The Communists did those things. But there it was, an official government statement that clearly told less than the whole truth but said without question that the United States had conducted aerial espionage missions and that this one, flown by Francis Gary Powers over the Soviet Union on May 1, 1960, had gone wrong.

In the days to come that statement would be repeatedly modified, and President Eisenhower would eventually shoulder the blame for authorizing the overflight. The Big Four Summit in Paris would collapse; Powers would be sentenced at a Moscow show trial; and Nikita Khrushchev would pound his shoe on the table at the United Nations. We wondered if the world was going to blow up.

Michael Beschloss has recaptured those days and their extraordinary tension with an eminently readable, swiftly paced history of an espionage program that depended on a remarkable airplane, enormous secrecy and, ultimately, the skill and bravery of pilots flying a machine so fragile that turbulence from other aircraft could knock its wings off.



The U-2 was the interim spy in the sky, a quick fix that could be deployed before the United States figured out how to get high resolution satellite cameras in orbit. To build the spy-plane, Kelly Johnson and his team at Lockheed's famed "skunk works" had to overcome daunting engineering challenges, including how the airplane could carry enough fuel to meet the range requirements and still power air-breathing engines in the rarefied atmosphere of 70,000-plus feet ("In the Museum" August/September). They came up with a flying machine with wings so long they require special wheels to keep them from dragging on the runway during takeoff.

The U-2 is the unifying concept of *Mayday*, the lens through which Beschloss examines a slice of Cold War history. It was not hard to sell President Eisenhower on the necessity for good intelligence, and in its four years of usefulness the U-2 disproved the existence of the bomber and missile gaps and allowed the president to keep the lid on defense expenditures. Even so, Beschloss documents in fascinating detail Eisenhower's concerns that the overflights would be seen by Kremlin leaders as provocative, and the president's attempts to minimize the flights' risks.

But, as with all of our technological toys, the temptation to use the U-2 was tremendous. Eventually that temptation overtook reasonable caution, and Eisenhower permitted a U-2 flight within a few days of the Paris summit—despite the dangers.

How and why did this happen? The answer could lie in a simple confluence of accidents and oversights. But it could involve something more sinister: the U-2 affair is often the jumping-off point for aviation-based conspiracy theories, theories claiming that certain right-wing elements in the United States will go to any lengths to prevent accommodations with the Soviets. The U-2 is sometimes cited as a precedent by those who implicate U.S. intelligence agencies in the demise of Korean Air Lines Flight 007, which resulted in 269 deaths and renewed U.S.-Soviet tensions.

While Beschloss wisely refrains from validating any of these theories, he does discuss the evidence around which they are built. And he hypothesizes—with ample justification, it seems—that government dissembling over the U-2's mission and fate was the first step in the disillusionment of Americans with their government that makes such conspiracy theories possible. Ultimately, it's a sad story, but also an intriguing and important one, and Beschloss tells it well.

—Douglas B. Feaver is the aviation writer for The Washington Post.

Apollo 11: Man's 1st Moon Landing. *Produced by NASA. Distributed by Finley-Holiday Films. 30 minute videotape. $34.95.*

The opening line, predictably enough, is "The *Eagle* has landed." Indeed, all the climactic scenes of this video—the *Apollo 11* countdown and launch at Cape Canaveral, Neil Armstrong's photographs of Edwin "Buzz" Aldrin lowering himself onto the surface of the moon, the stars and stripes gallantly pretending to wave in a nonexistent lunar breeze—are as familiar to most Americans as Campbell's soup cans.

Andy Warhol rescued the Campbell's soup can from the anonymity of mass production by painting one larger than life-size. The NASA producers of this videotape take as their subject a drama which is by its very nature larger than life, and make it fun. In doing so, they do not make the story of the first manned lunar landing any less awe-inspiring or momentous. They simply make it accessible and appealing again to those who've seen it all before.

The best-remembered images and critical scenes are all here, but they are interwoven with lighter moments and with some of the quirky realities of the summer of 1969. Film footage of the tension and drama at mission control and the launch pad during countdown are interrupted by flashes of the now-classic photographs of Aldrin on the moon, as if to remind viewers that they know the end of this tale even before the telling's begun. Footage of the astronauts shaving, exercising, and checking off their check lists during their voyage to the moon is included—and, since these scenes were shot at low speeds, they have a ridiculous, jerky look.

The soundtrack, too, merges documentary seriousness with a lighter, occasionally even wry (or does it only seem that way to us now?) tone. Excerpts from Kennedy's 1961 speech, in which he pledges to send a man to the moon "before this decade is out," are used to good effect. So too are interviews with Armstrong, Aldrin, and Michael Collins, which serve as the soundtrack to a scene of the lunar and command modules drawing towards each other for their rendezvous and return to Earth. Finally, who welcomes the astronauts back to Earth with a lofty speech about how "The Spirit of Apollo can bring the people of the world together in peace"? Richard Nixon, of course.

All in all, *Apollo 11* gives viewers a pleasant and entertaining way to look back at a happier time in the history of the American space program.

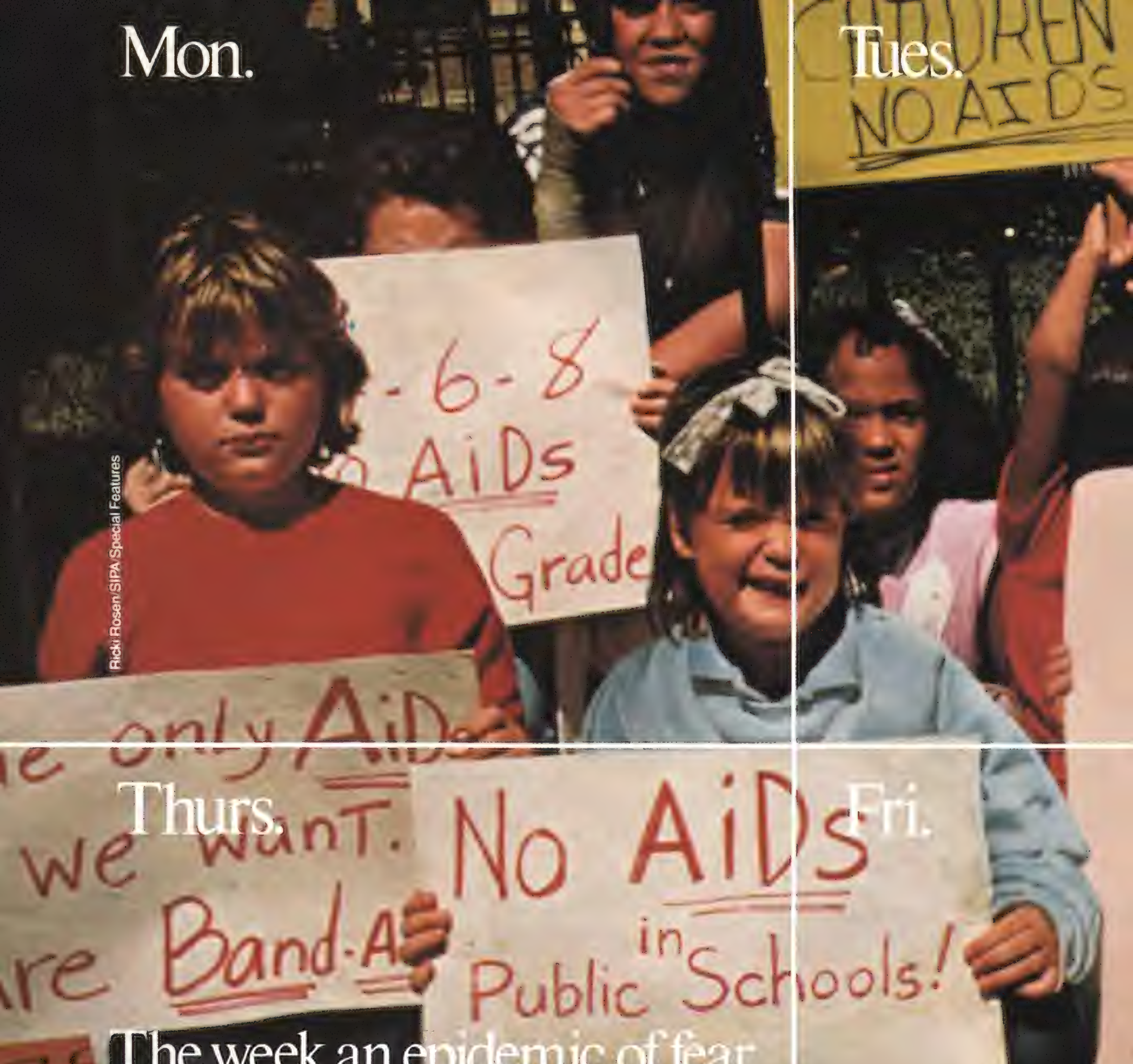
—*Katie Janssen*

World Without Walls: Beryl Markham's African Memoir. *Produced by KQED. Narrated by Diana Quick and Lyle Talbot. Airing on PBS October 8, 10pm.*

Based on Beryl Markham's *West With the Night* ("Moments & Milestones," June/July), "World Without Walls" gives viewers the images to go along with Markham's words about her adventures as an aviation pioneer. Movietone footage of her record-making 1936 transatlantic flight is highlighted. The documentary also offers glimpses into Markham's private life.

"World Without Walls" pays fitting tribute to a remarkable woman.

—*Katie Janssen*



Ricki Rosen/SIPA Special Features

The week an epidemic of fear received an injection of truth.

Only a few years ago, you didn't even know it was there, silently spreading. Then several doctors noticed a strange new phenomenon. Healthy young men were suddenly contracting rare and unusual illnesses.

When the Centers for Disease Control correlated the data coming in, public-health officials realized a new enemy had taken the field. They called it AIDS (Acquired Immune Deficiency Syndrome). From that day on, the battle was joined.

It's been a battle we've all had to fight, usually within ourselves. You try to be fair, understanding. But suppose it was your child sitting at the desk next to an AIDS victim? Would reason prevail?

From the time of our first cover story on AIDS back in 1983, Newsweek has realized that something alien was becoming part of our lives—affecting our friendships, our schools, even our politics.

As AIDS grew, Newsweek's coverage grew. Bringing a dose of truth to all those stricken with the most widespread symptom of this disease—fear.

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At Newsweek, whether a story covers a day, or a decade, we cover it all the way. You see, as long as it's part of your life, it's part of our life.

Newsweek.

Why it happened. What it means.

Credits & Further Reading

The Flight of the Dragonfly. *Richard Wolkomir* is a freelance magazine writer from Vermont whose work has appeared in *Smithsonian, Reader's Digest, Omni,* and other magazines. In 1984 he received the American Association for the Advancement of Science's Westinghouse Award for distinguished magazine science writing.
Further Information: The Dragonfly by Pat Clay (Adam and Charles Black, London, 1978).
Insect Flight, edited by R.C. Rainey (Wiley, New York, 1976).

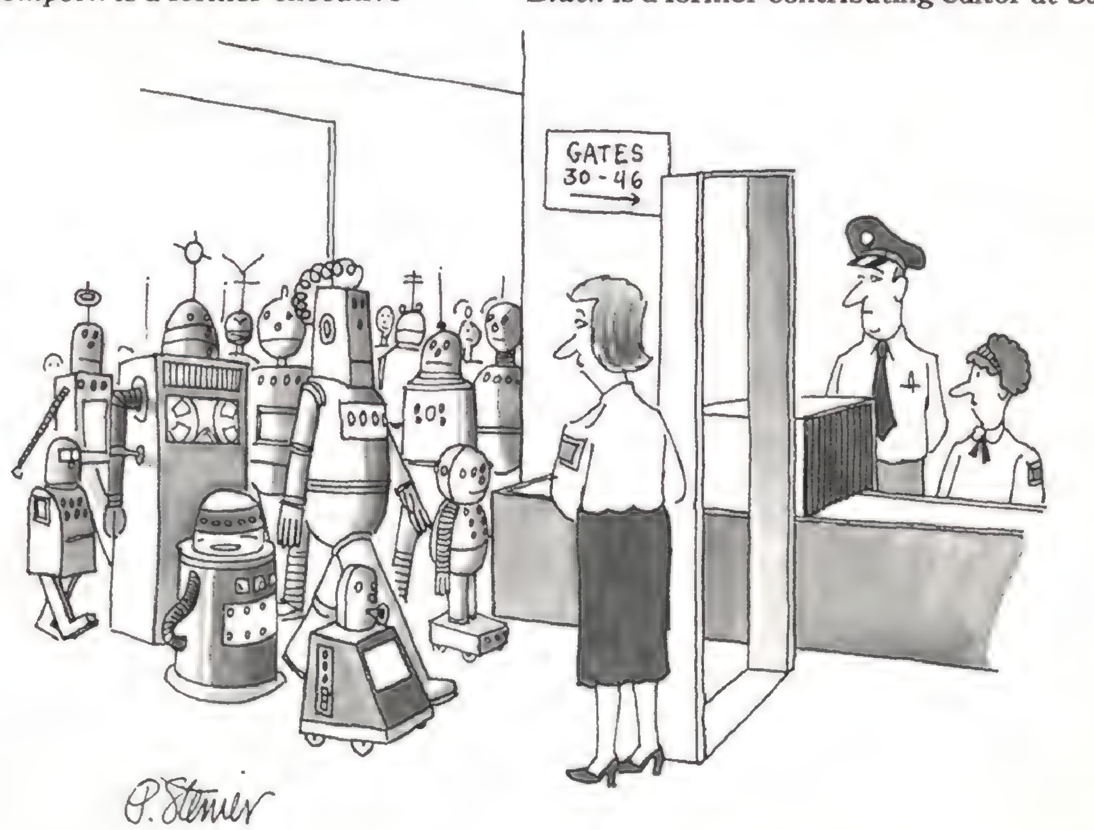
Solid-Fuel Rockets. *Kurt Stehling* is scientist emeritus for the National Oceanic and Atmospheric Administration, and has been involved in senior capacities as a rocket research engineer at Bell Aircraft (Aerospace), Project Vanguard, and NASA.
Further Information: The Rocket: The History and Development of Rocket and Missile Technology by David Baker (New Cavendish Books, London, 1978).
History of Rocketry and Space Travel by Wernher von Braun and Frederick I. Ordway III (Thomas Y. Crowell Co., New York, 1966).

The Great American Pilot Shortage. *Steven Thompson* is a former executive editor of the Aircraft Owners and Pilots Association magazine, *Pilot,* and the author of a series of spy/adventure novels. His "Hard Times in Hangartown" appeared in the April/May 1986 issue of *Air & Space/ Smithsonian.*

Voyager. *Junius Ellis,* formerly a senior editor at *Money* magazine, is a New York-based freelance writer. His writing has appeared in *Reader's Digest,* the *New York Times,* the *Washington Post,* and elsewhere.
Further Information: "The *Voyager*'s bid to girdle the world is no mere canard" by Edwards Park in *Smithsonian,* Vol. 15, No. 11, February 1985.

Air at the Fair. *Daniel Jack Chasan* is the business editor of *The Weekly: Seattle's News Magazine.* His freelance work has appeared in *Science 86, Smithsonian, The New Yorker, Esquire,* and other magazines. He lives on Vashon Island, Washington.
Further Information: To contact Expo 86, write: Expo Info, P.O. Box 1800, Vancouver, B.C., Canada V6C 3A2, or call (604) 660-3976.

Here's Looking at You, Sol. *Randall Black* is a former contributing editor at *Sci-*



ence Digest, and has been a freelance science writer since 1981. He lives in Costa Mesa, California, where he is working on a book about habitable planets.
Further Information: Secrets of the Sun by Ronald Giovanelli (Cambridge University Press, Cambridge, 1984).
Our Turbulent Sun by Kendrick Frazier (Prentice-Hall, Englewood Cliffs, N.J., 1982).

Something Special in the Air. *Patricia Trenner* is an associate editor at *Air & Space/Smithsonian.*
Further Information: The Legendary DC-3 by Carroll V. Glines and Wendell F. Mosely (Von Nostrand Reinhold, New York, 1979).

The $457 Astronaut. For 27 years, *Benjamin Lawless* was the director of exhibits at the Smithsonian Institution's National Museum of Natural History. His writing credits include *Smithsonian* and *Boating* magazines, and as a freelance museum design consultant he has worked for the National Civil Rights Center in Memphis.
Further Information: Animal Astronauts: They Opened the Way to the Stars by Clyde R. Bergwin (Prentice-Hall, Englewood Cliffs, N.J., 1963).

The Man Who Would Be Right. *Anthony Liversidge* has written on subjects ranging from astrophysics to computers for *Omni, Science Digest,* and *New York* magazines, with a special interest in the connection between personality and achievement. He lives in New York.
Further Information: The Origin of the Solar System, edited by S.F. Dermott (Wiley, New York, 1976).
Solar System by Kendrick Frazier (Time-Life Books, Alexandria, Va., 1985).
"The *Voyager 2* Encounter with the Uranian System" in *Science,* Vol. 233, No. 4759, July 4, 1986.

Breathing Lessons. The senior editor of *Sky and Telescope* magazine, *J. Kelly Beatty* hopes some day to Valsalva in orbit. His last article for *Air & Space/Smithsonian* was "Spaceport West," in the April/May 1986 issue.

Hello? Hello? *Phil Cohan,* a freelance writer, is a former Washington newsman and a veteran of the United States Foreign Service. His last work for *Air & Space/Smithsonian,* "Dollars from Heaven," appeared in the June/July 1986 issue.

Ancient Aerodynamics. *Jake Page* is a consulting editor for *Air & Space/Smithsonian.* His most recent book is *Pastoral* (Norton, New York, 1985).

Upcoming Features Just Over the Horizon

David Nance

Curator of Cosmic Dust—It's a dirty job, but somebody has to do it. And Michael Zolensky seems to enjoy doing it: collecting, preserving, and analyzing the specks of matter that drift into the upper atmosphere. (In fact, Zolensky and others do much of their work in clean rooms. *You* figure it out.)

Soaring Museum—A tour through the memorabilia of sailplanes, gliding, and soaring that's drawn thousands of people of all ages to Elmira, New York's National Soaring Museum. Visitors meet up with Wright gliders as well as tales of harrowing rescue from Asian jungles.

Tiepolo—Hardly a household name and yet not just another painter, this old master saw the sky in a way that influenced art forever.

Jonathan Atkin

Robert Lightfoot

The Little Airline of the Lake—Since 1930, Island Airlines of Ohio has been the link between the islands off the shores of Lake Erie and the goods and services of the mainland. And though the requests for passage range from people to pets, island residents say Island's service is good.

Jordan Coonrad

Orbis—Inside an old DC-8 is a complete hospital dedicated to saving the vision of patients all over the world. Volunteer medical staff and flight crews have meant the difference between blindness and sight to thousands of grateful citizens.

All Quiet on the Launch Pad—With no rockets to send up, a spaceport has little to do but twiddle its thumbs. The communities surrounding Florida's Kennedy Space Center are responding to the setbacks in the U.S. space program with a combination of plucky resolve and some gloom over the uncertainty the future holds.

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San Francisco ←→ Bangor	2780	5:41	6:54
Bangor ←→ London	3073	6:33	6:58

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